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(54) **USER FRIENDLY INTERFACE FOR CONTROL UNIT**

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CPC ***G05D 23/19*** (2013.01); *F24F 2011/0091* (2013.01); ***G05D 23/1902*** (2013.01); *F24F 2221/32* (2013.01); ***F24F 11/0086*** (2013.01)
USPC ..... **700/276**; 236/1 C; 236/91 D

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USPC ..... 700/276; 236/1 C, 91 D, 91 R, 94
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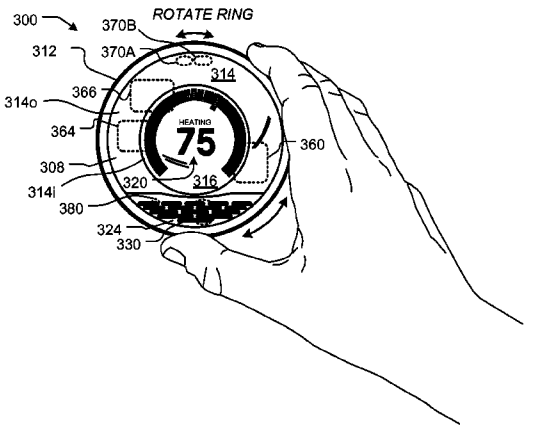
(57) **ABSTRACT**

A user-friendly programmable thermostat is described that includes a central electronic display surrounded by a ring that can be rotated and pressed inwardly to provide user input in a simple and elegant fashion. The current temperature and setpoint are graphically displayed as prominent tick marks. Different colors and intensities can be displayed to indicate currently active HVAC functions and an amount of heating or cooling required to reach a target temperature. The setpoint can be altered by user rotation of the ring. The schedule can be displayed and altered by virtue of rotations and inward pressings of the ring. Initial device set up and installation, the viewing of device operation, the editing of various settings, and the viewing of historical energy usage information are made simple and elegant by virtue of the described form factor, display modalities, and user input modalities of the device.

29 Claims, 45 Drawing Sheets



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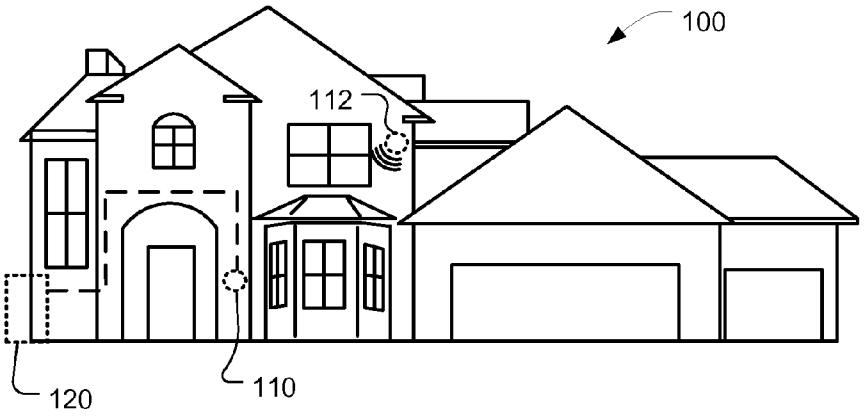
100
112
120
110

FIG. 1

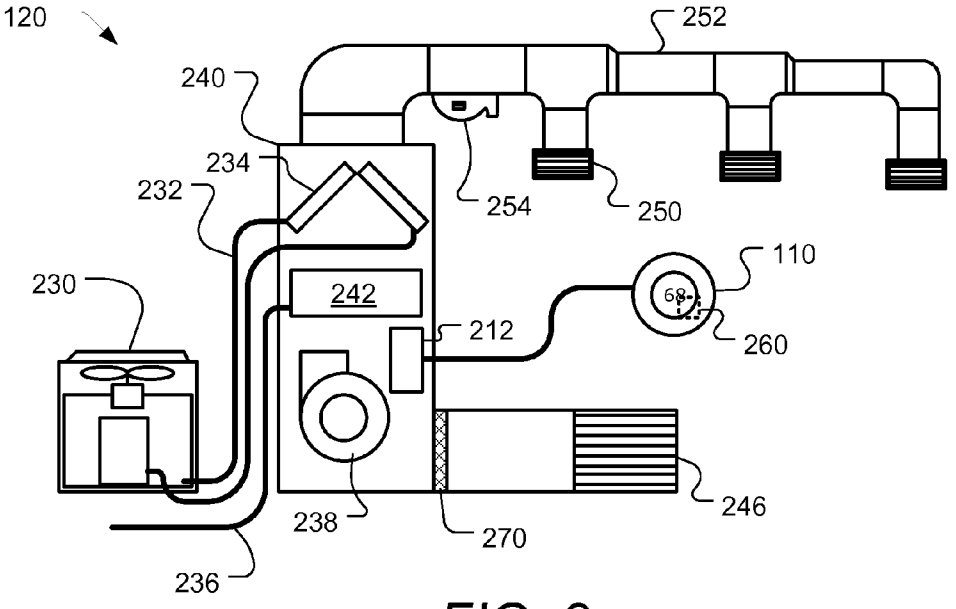
120
252
240
234
232
254
250
110
230
242
212
68
260
246
238
270
236

FIG. 2

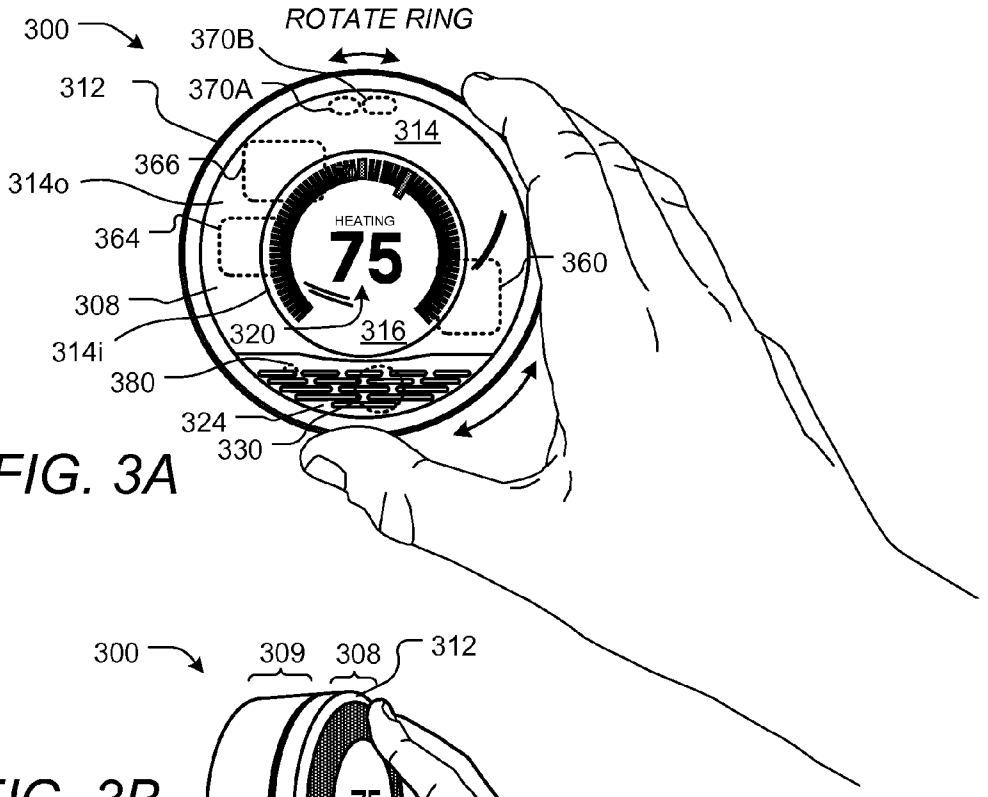

FIG. 3A

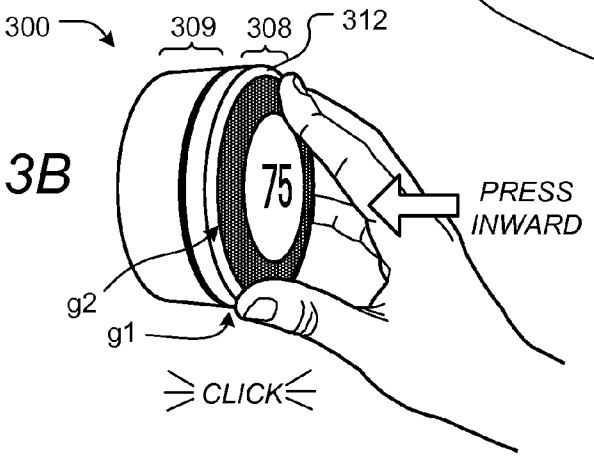

FIG. 3B

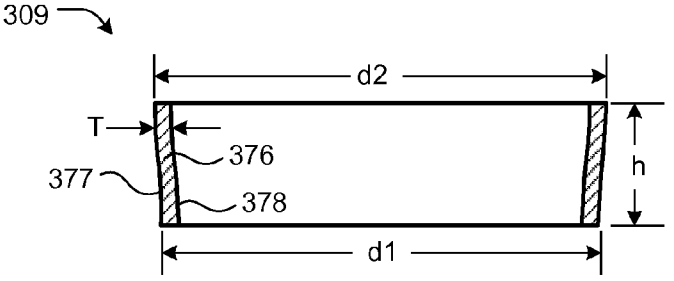

FIG. 3C

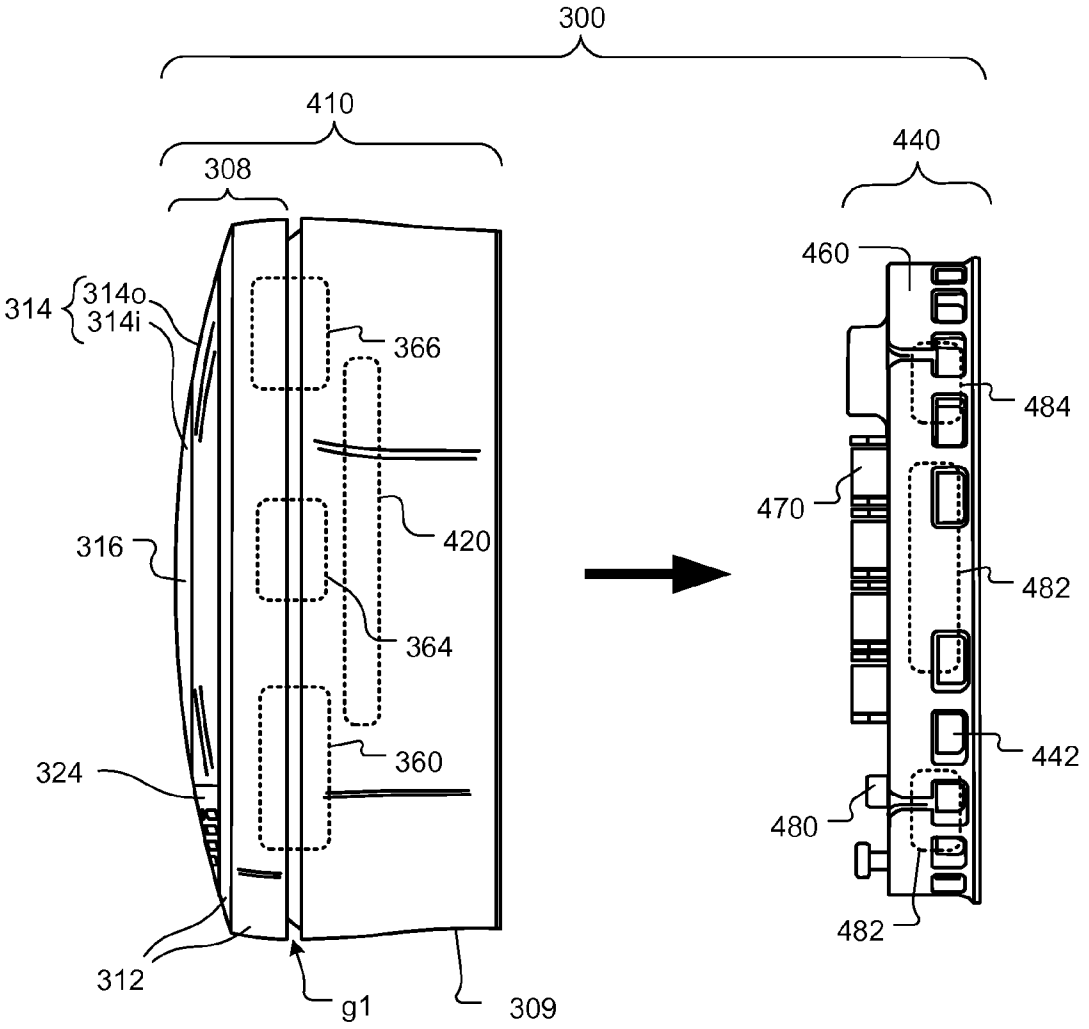
300
410
308
440
314
314o
314i
316
324
312
g1
309
366
420
364
360
460
484
470
482
442
480
482

FIG. 4

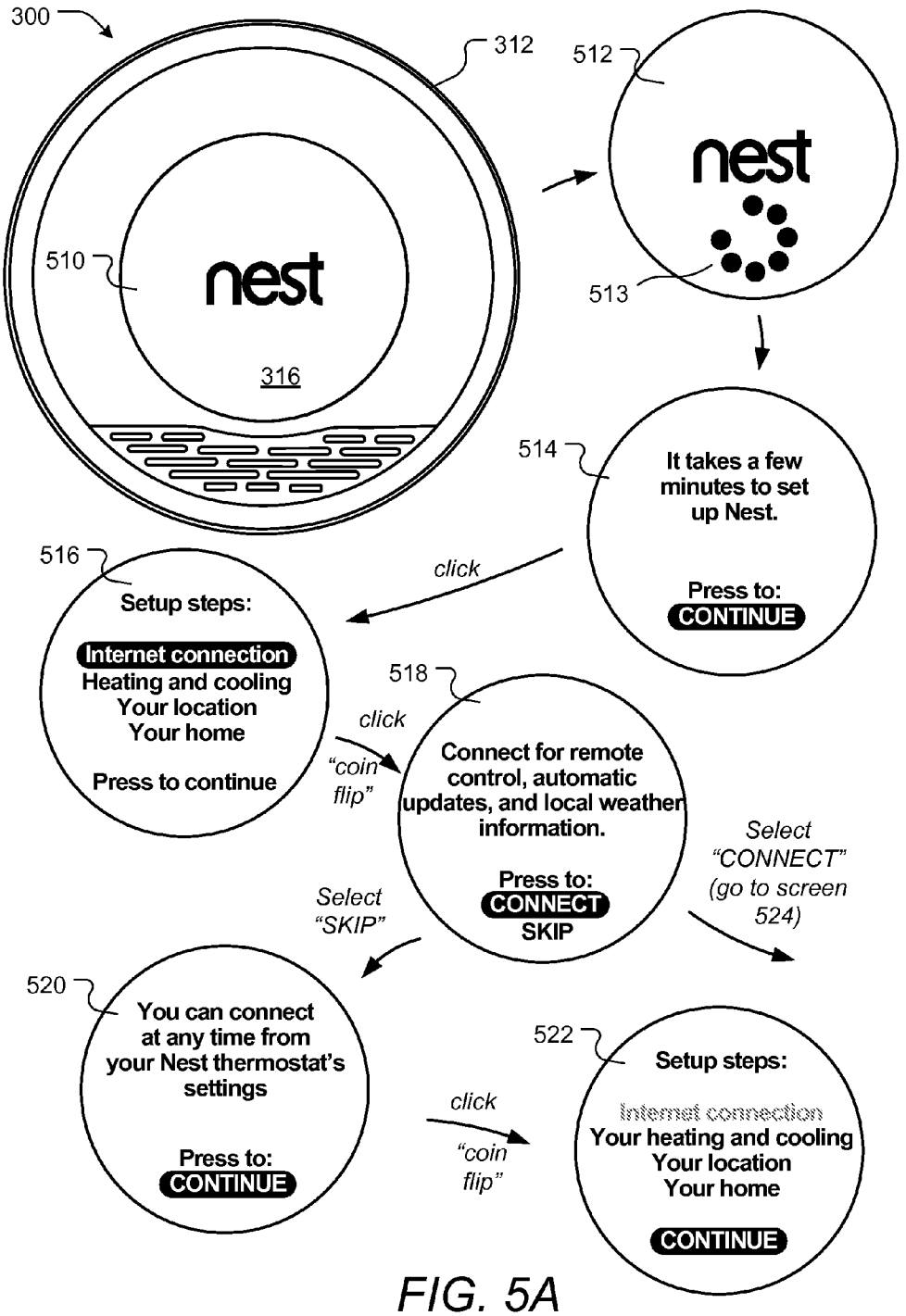
300
312
512
nest
510
nest
316
513
514
It takes a few minutes to set up Nest.
Press to:
CONTINUE
516
click
Setup steps:
Internet connection
Heating and cooling
Your location
Your home
Press to continue
518
click
"coin flip"
Connect for remote control, automatic updates, and local weather information.
Press to:
CONNECT
SKIP
Select "CONNECT" (go to screen 524)
Select "SKIP"
520
You can connect at any time from your Nest thermostat's settings
Press to:
CONTINUE
click
"coin flip"
522
Setup steps:
Internet connection
Your heating and cooling
Your location
Your home
CONTINUE

FIG. 5A

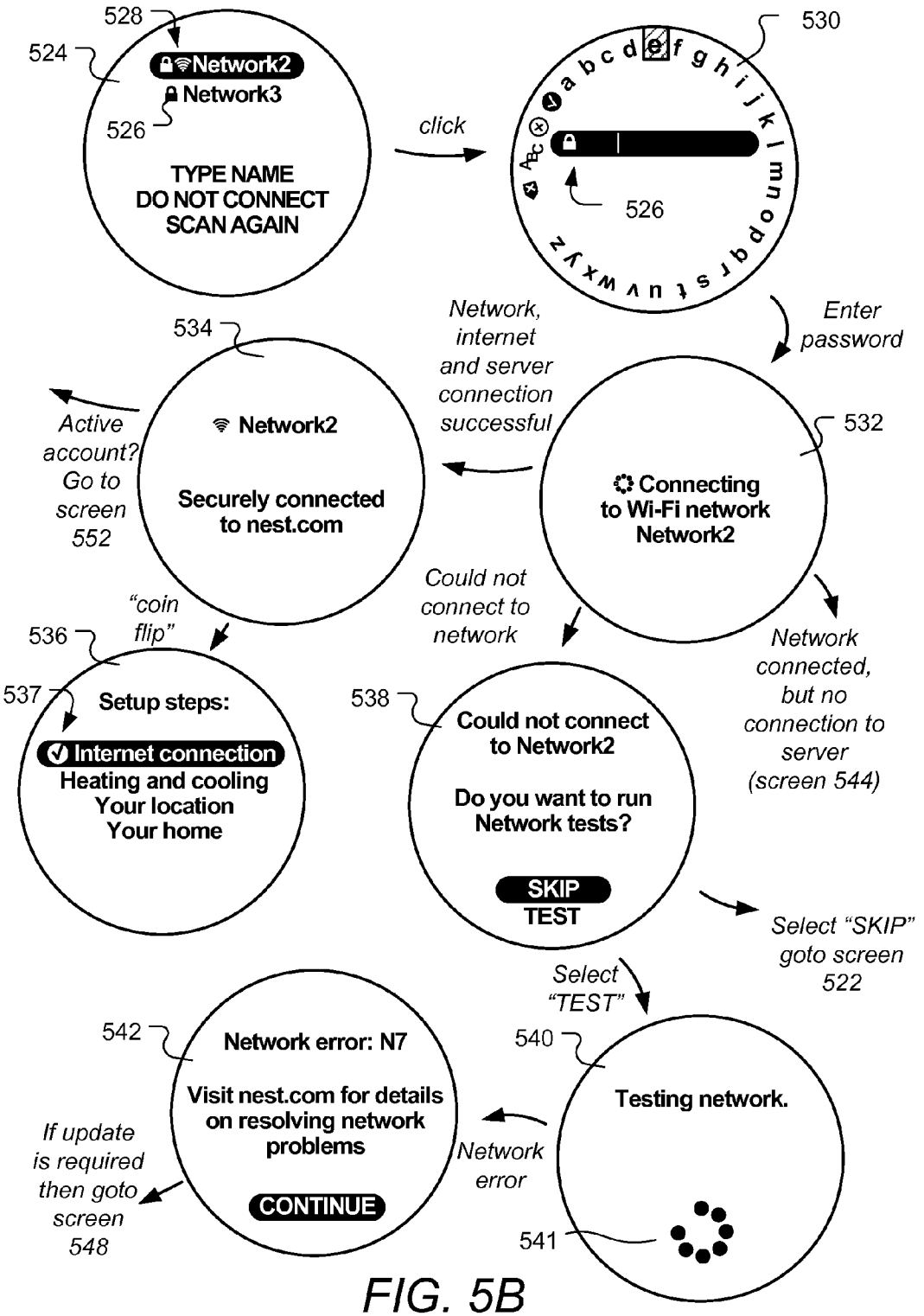
528
524
Network2
Network3
526
TYPE NAME
DO NOT CONNECT
SCAN AGAIN
click
530
526
Enter password
Network, internet and server connection successful
532
Connecting to Wi-Fi network Network2
534
Network2
Securely connected to nest.com
Active account? Go to screen 552
"coin flip"
536
537
Setup steps:
Internet connection
Heating and cooling
Your location
Your home
Could not connect to network
538
Could not connect to Network2
Do you want to run Network tests?
SKIP TEST
Network connected, but no connection to server (screen 544)
Select "SKIP" goto screen 522
Select "TEST"
540
Testing network.
541
Network error
542
Network error: N7
Visit nest.com for details on resolving network problems
CONTINUE
If update is required then goto screen 548

FIG. 5B

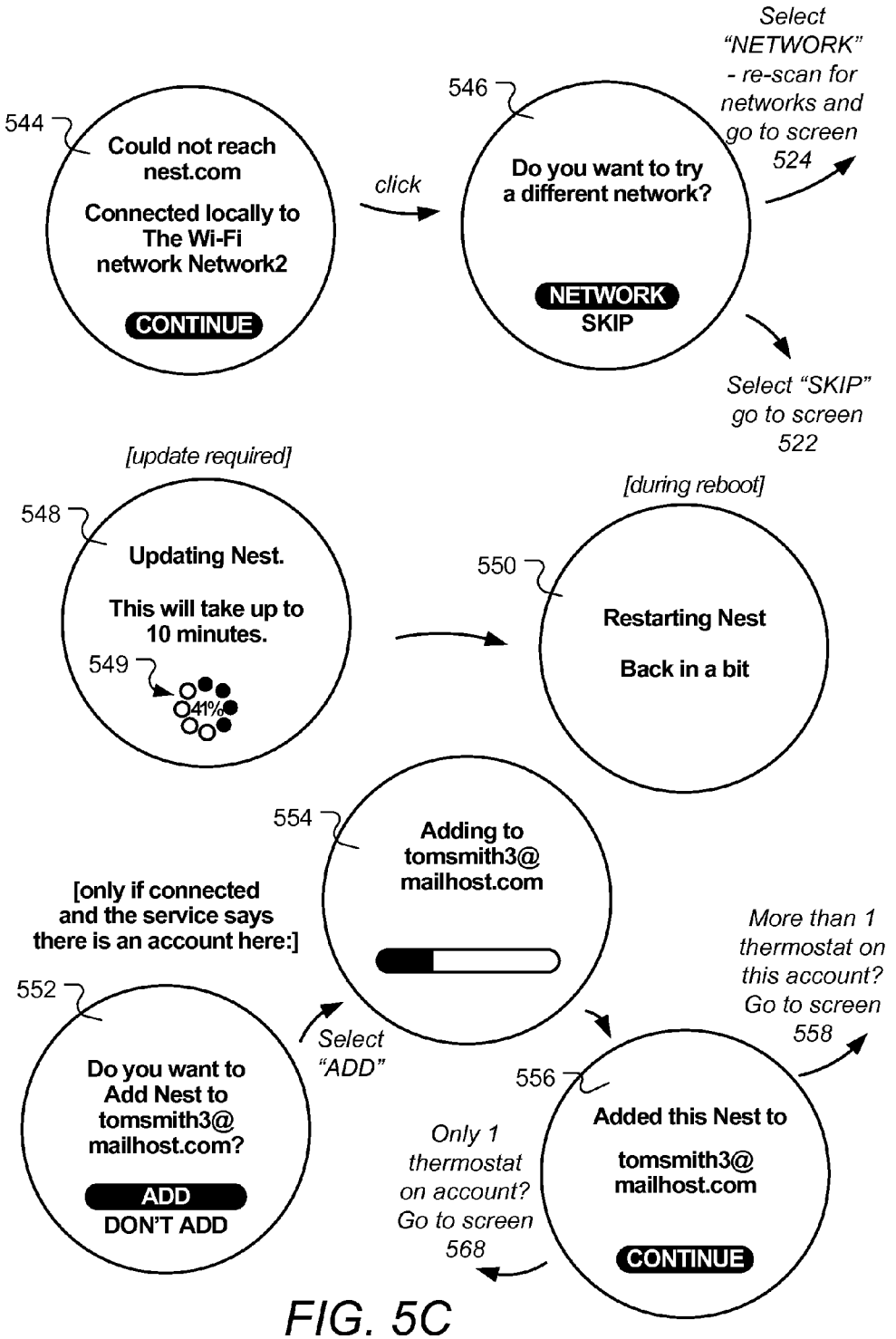
544
Could not reach nest.com
Connected locally to The Wi-Fi network Network2
CONTINUE
click
546
Do you want to try a different network?
NETWORK
SKIP
Select "NETWORK" - re-scan for networks and go to screen 524
Select "SKIP" go to screen 522
[update required]
548
Updating Nest.
This will take up to 10 minutes.
549
41%
[during reboot]
550
Restarting Nest
Back in a bit
554
Adding to tomsmith3@ mailhost.com
[only if connected and the service says there is an account here:]
552
Do you want to Add Nest to tomsmith3@ mailhost.com?
ADD
DON'T ADD
Select "ADD"
More than 1 thermostat on this account? Go to screen 558
556
Added this Nest to tomsmith3@ mailhost.com
CONTINUE
Only 1 thermostat on account? Go to screen 568

FIG. 5C

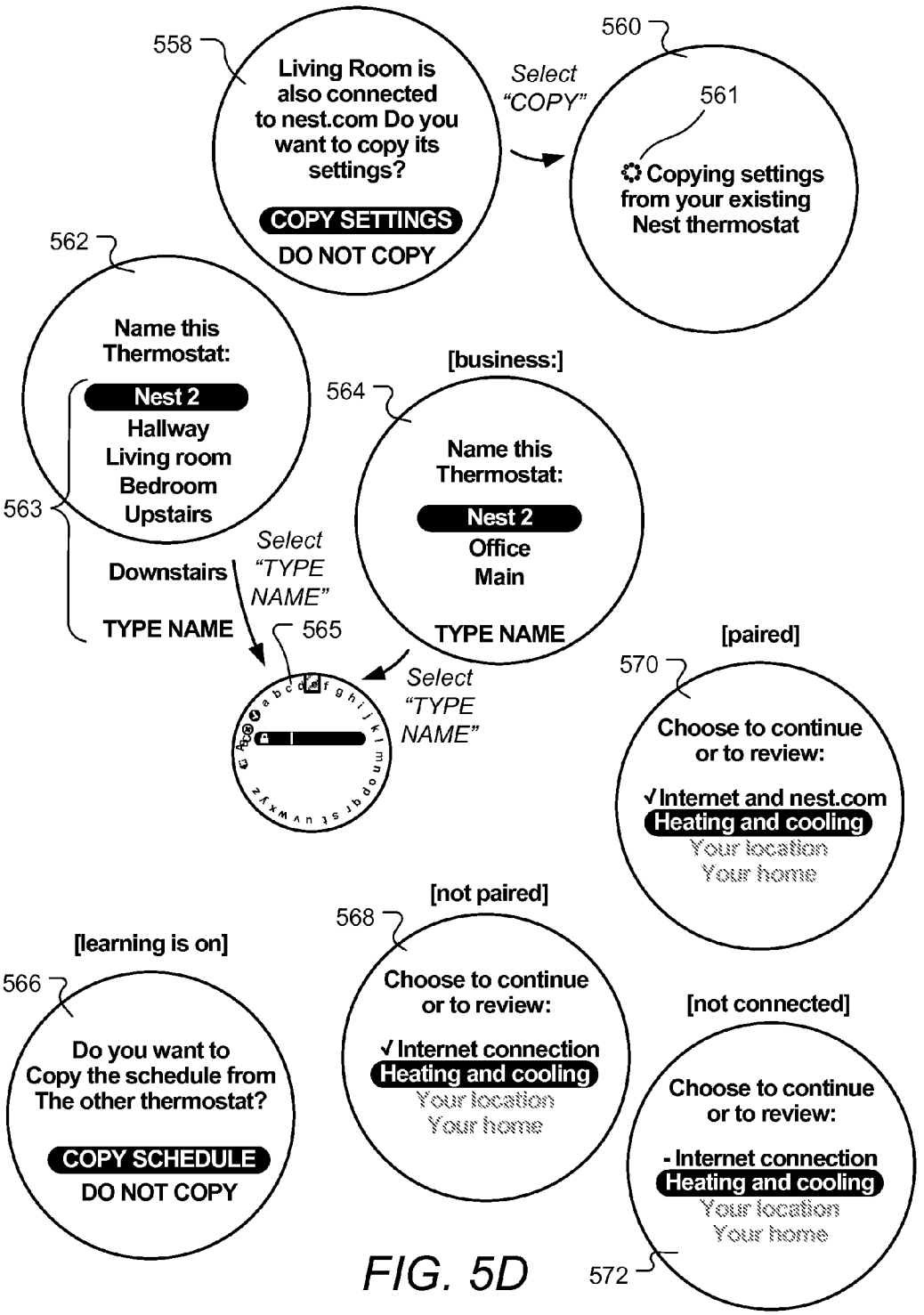
558
Living Room is also connected to nest.com Do you want to copy its settings?
COPY SETTINGS
DO NOT COPY
Select "COPY"
560
561
Copying settings from your existing Nest thermostat
562
Name this Thermostat:
Nest 2
Hallway
Living room
Bedroom
Upstairs
563
Downstairs
TYPE NAME
Select "TYPE NAME"
565
[business:]
564
Name this Thermostat:
Nest 2
Office
Main
TYPE NAME
Select "TYPE NAME"
[paired]
570
Choose to continue or to review:
√Internet and nest.com
Heating and cooling
Your location
Your home
[not paired]
568
Choose to continue or to review:
√Internet connection
Heating and cooling
Your location
Your home
[learning is on]
566
Do you want to Copy the schedule from The other thermostat?
COPY SCHEDULE
DO NOT COPY
[not connected]
Choose to continue or to review:
- Internet connection
Heating and cooling
Your location
Your home
572

FIG. 5D

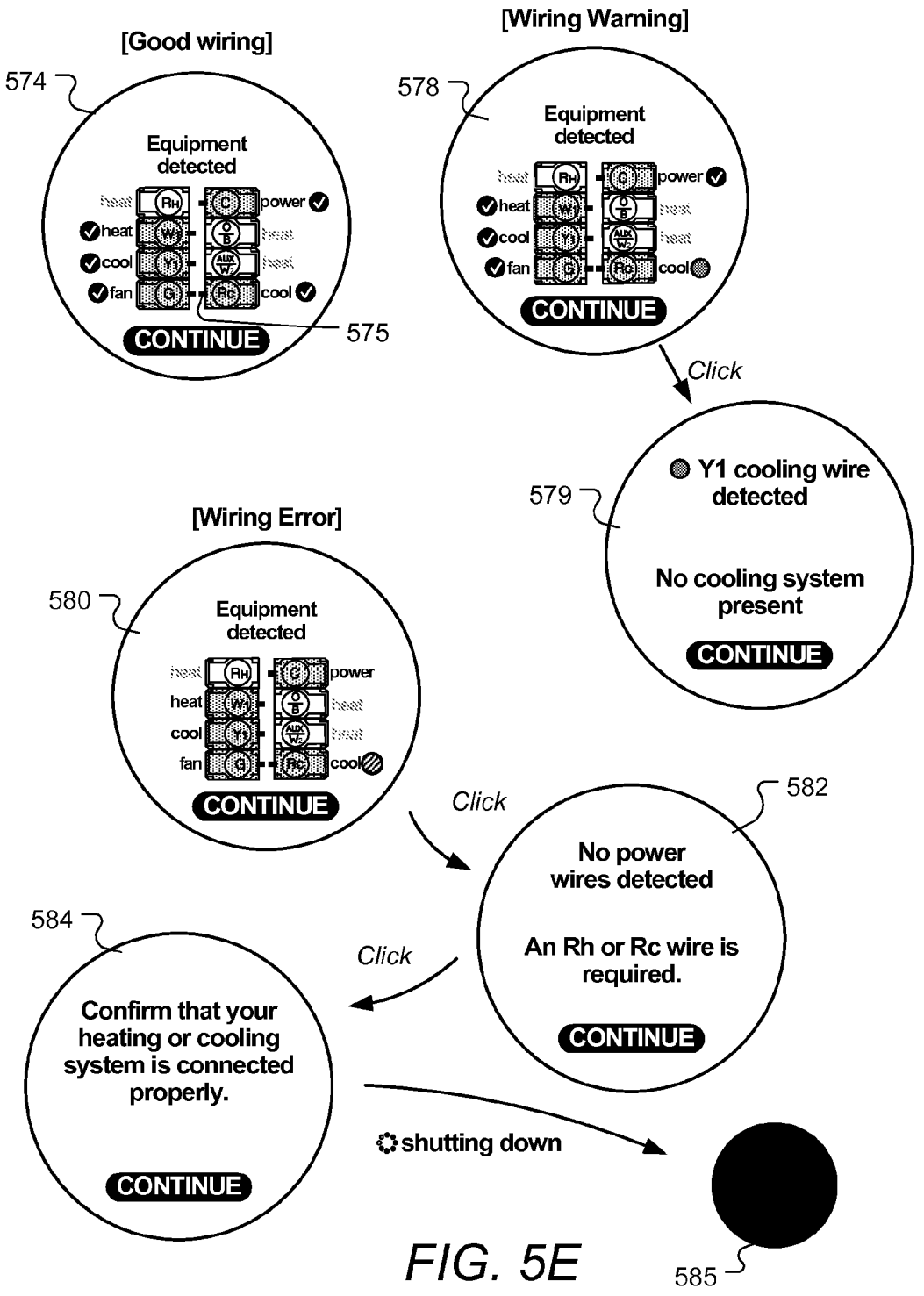
[Good wiring]
574
Equipment detected
power
heat
cool
fan
cool
CONTINUE
575
[Wiring Warning]
578
Equipment detected
power
heat
cool
fan
cool
CONTINUE
Click
579
Y1 cooling wire detected
No cooling system present
CONTINUE
[Wiring Error]
580
Equipment detected
power
heat
cool
fan
cool
CONTINUE
Click
582
No power wires detected
An Rh or Rc wire is required.
CONTINUE
Click
584
Confirm that your heating or cooling system is connected properly.
CONTINUE
shutting down
585

FIG. 5E

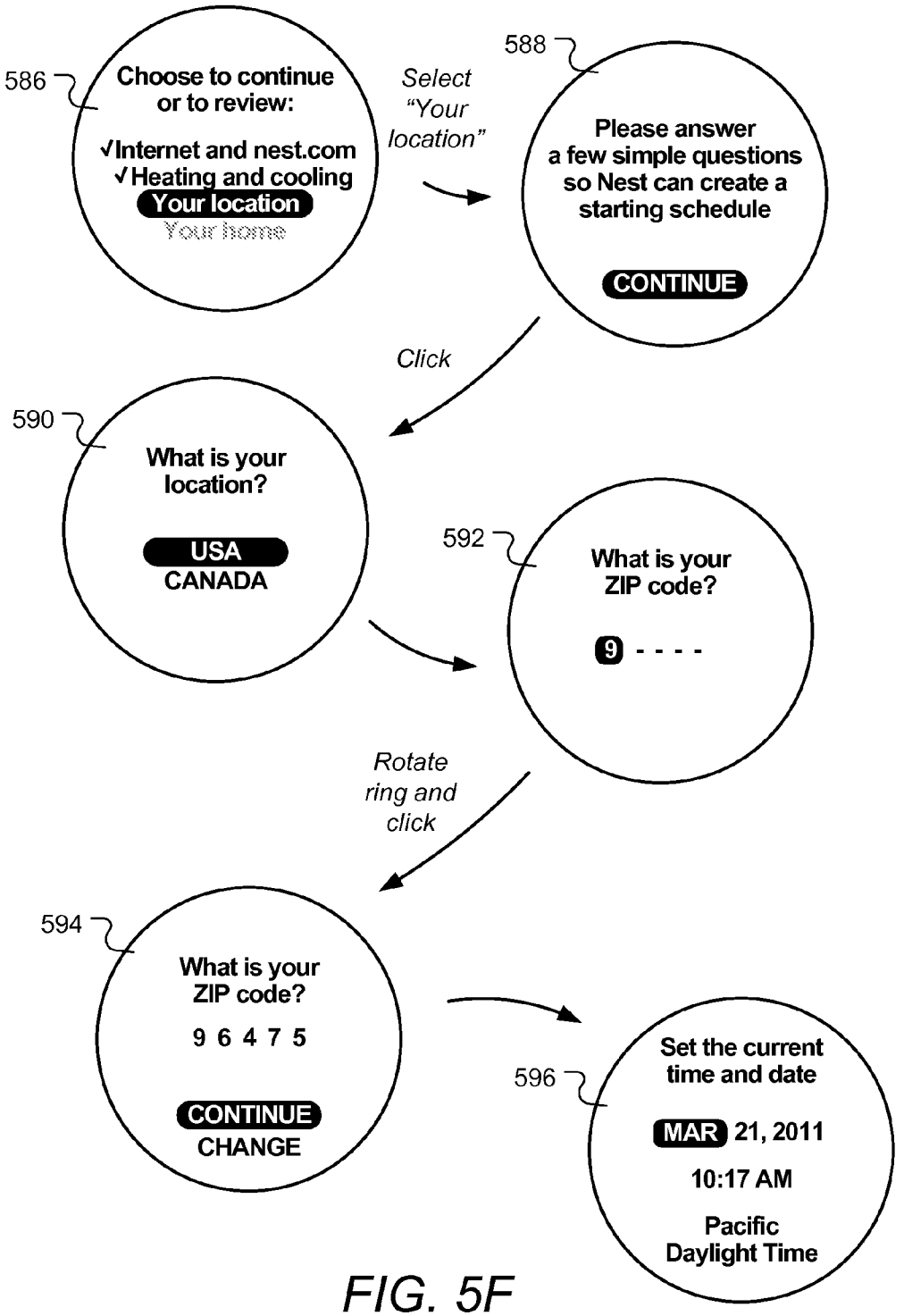
586
Choose to continue or to review:
✓Internet and nest.com
✓Heating and cooling
Your location
Your home
Select "Your location"
588
Please answer a few simple questions so Nest can create a starting schedule
CONTINUE
Click
590
What is your location?
USA
CANADA
592
What is your ZIP code?
9 - - - -
Rotate ring and click
594
What is your ZIP code?
9 6 4 7 5
CONTINUE
CHANGE
596
Set the current time and date
MAR 21, 2011
10:17 AM
Pacific Daylight Time

FIG. 5F

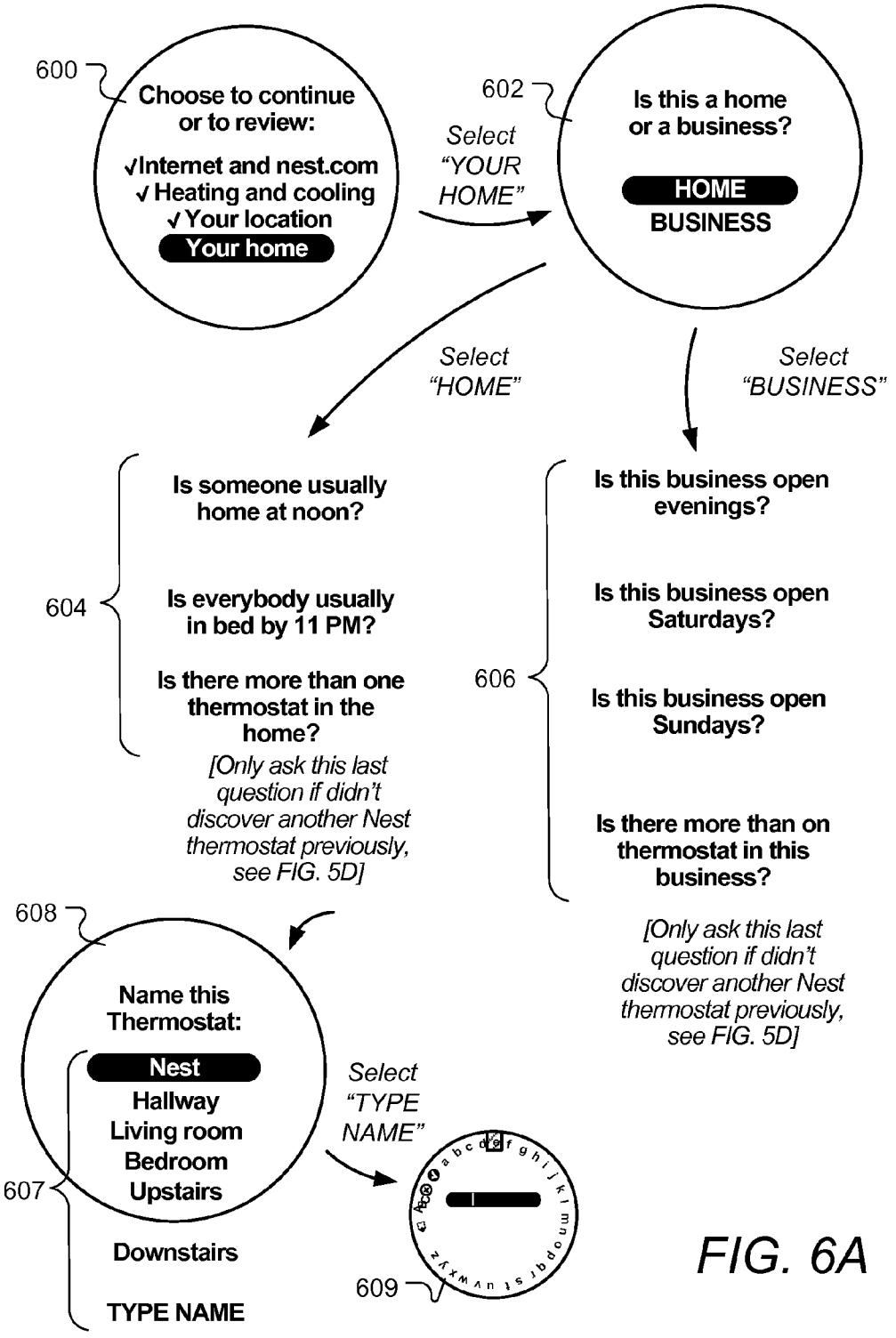
600
Choose to continue or to review:
√Internet and nest.com
√ Heating and cooling
√ Your location
Your home
602
Is this a home or a business?
HOME
BUSINESS
Select "YOUR HOME"
Select "HOME"
Select "BUSINESS"
604
Is someone usually home at noon?
Is everybody usually in bed by 11 PM?
Is there more than one thermostat in the home?
[Only ask this last question if didn't discover another Nest thermostat previously, see FIG. 5D]
606
Is this business open evenings?
Is this business open Saturdays?
Is this business open Sundays?
Is there more than on thermostat in this business?
[Only ask this last question if didn't discover another Nest thermostat previously, see FIG. 5D]
608
Name this Thermostat:
Nest
Hallway
Living room
Bedroom
Upstairs
607
Downstairs
TYPE NAME
Select "TYPE NAME"
609

FIG. 6A

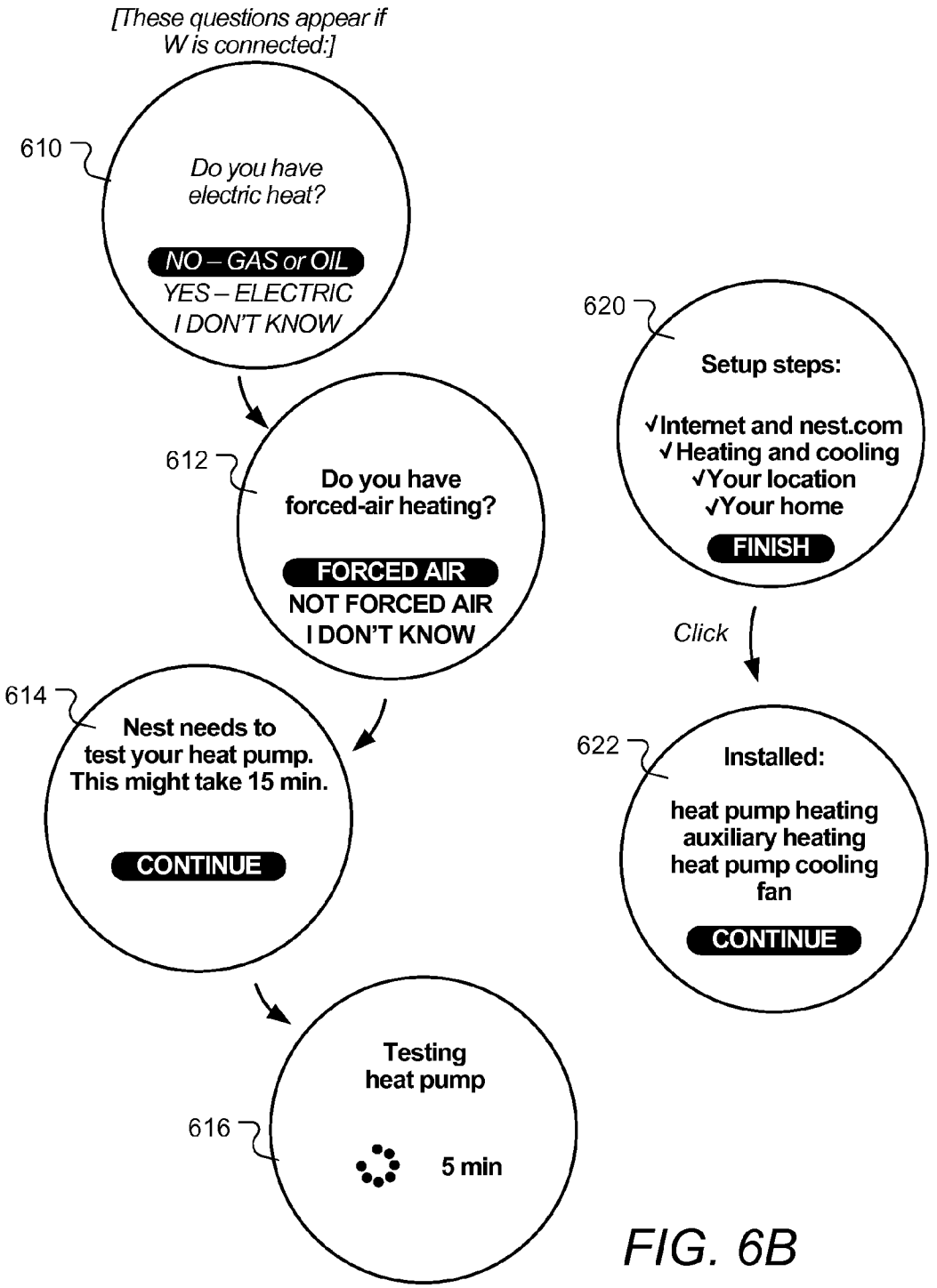
[These questions appear if W is connected:]
610
Do you have electric heat?
NO – GAS or OIL
YES – ELECTRIC
I DON'T KNOW
612
Do you have forced-air heating?
FORCED AIR
NOT FORCED AIR
I DON'T KNOW
614
Nest needs to test your heat pump. This might take 15 min.
CONTINUE
616
Testing heat pump
5 min
620
Setup steps:
√Internet and nest.com
√Heating and cooling
√Your location
√Your home
FINISH
Click
622
Installed:
heat pump heating
auxiliary heating
heat pump cooling
fan
CONTINUE

FIG. 6B

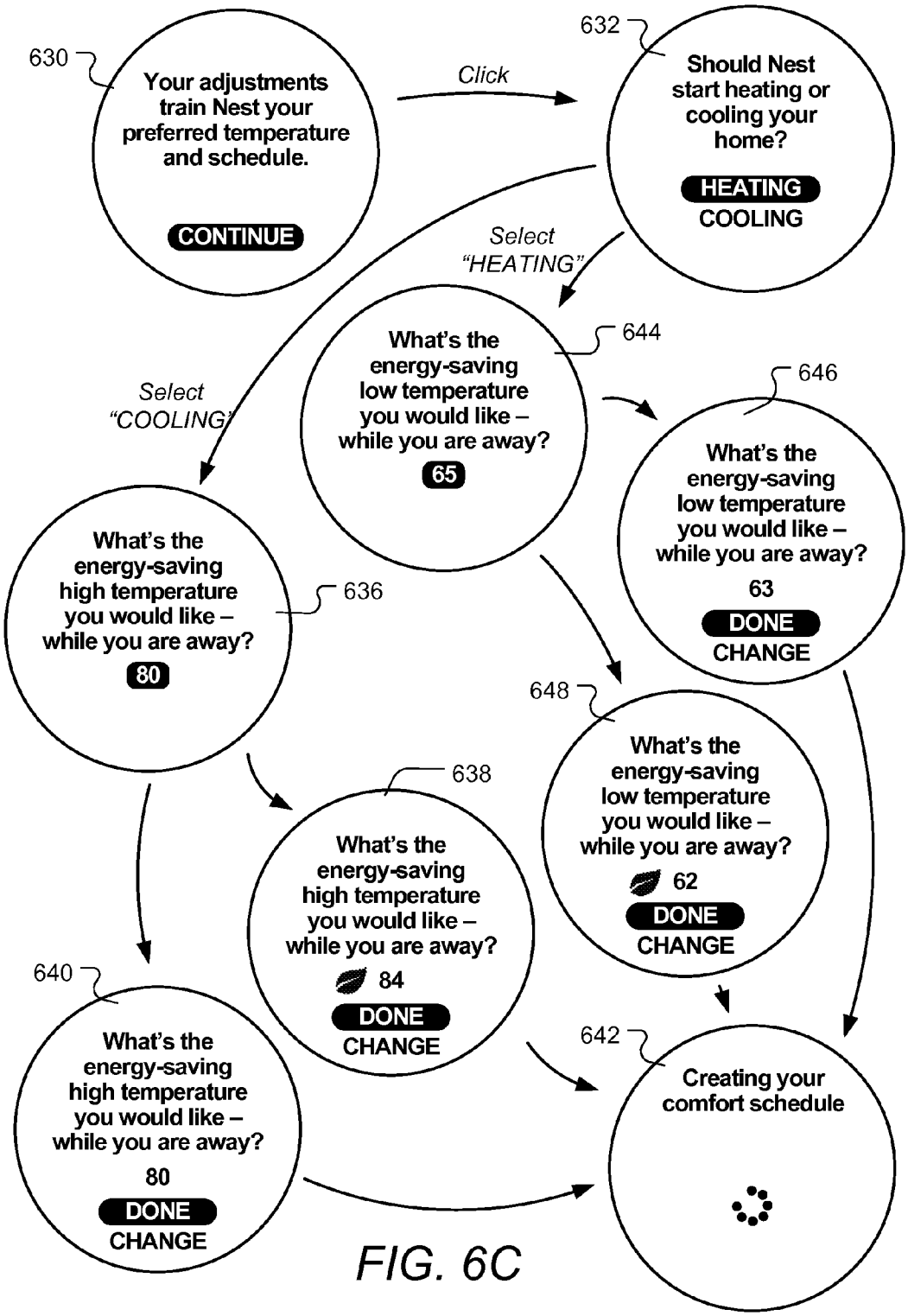
630
Your adjustments train Nest your preferred temperature and schedule.
CONTINUE
Click
632
Should Nest start heating or cooling your home?
HEATING
COOLING
Select "HEATING"
Select "COOLING"
644
What's the energy-saving low temperature you would like – while you are away?
65
646
What's the energy-saving low temperature you would like – while you are away?
63
DONE
CHANGE
636
What's the energy-saving high temperature you would like – while you are away?
80
648
What's the energy-saving low temperature you would like – while you are away?
62
DONE
CHANGE
638
What's the energy-saving high temperature you would like – while you are away?
84
DONE
CHANGE
640
What's the energy-saving high temperature you would like – while you are away?
80
DONE
CHANGE
642
Creating your comfort schedule

FIG. 6C

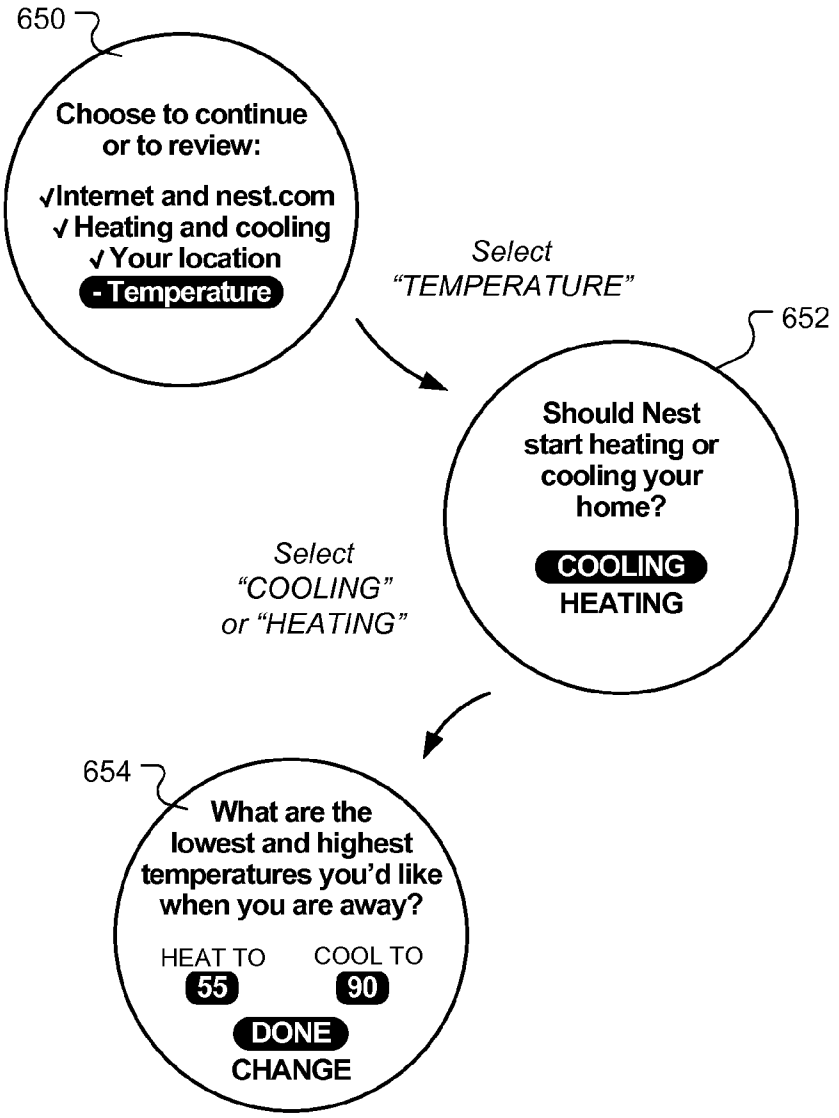
650
Choose to continue or to review:
√Internet and nest.com
√ Heating and cooling
√ Your location
- Temperature
Select "TEMPERATURE"
652
Should Nest start heating or cooling your home?
COOLING
HEATING
Select "COOLING" or "HEATING"
654
What are the lowest and highest temperatures you'd like when you are away?
HEAT TO
55
COOL TO
90
DONE
CHANGE

FIG. 6D

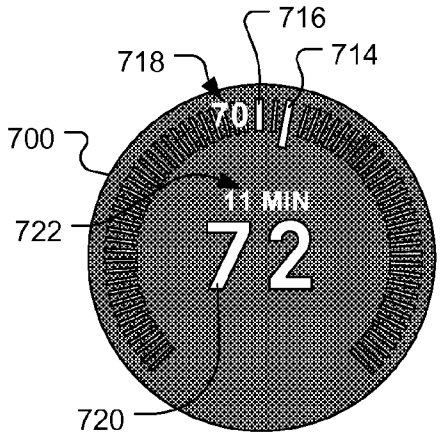

FIG. 7A

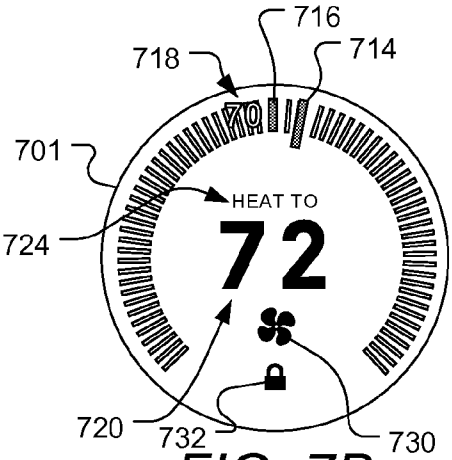

FIG. 7B

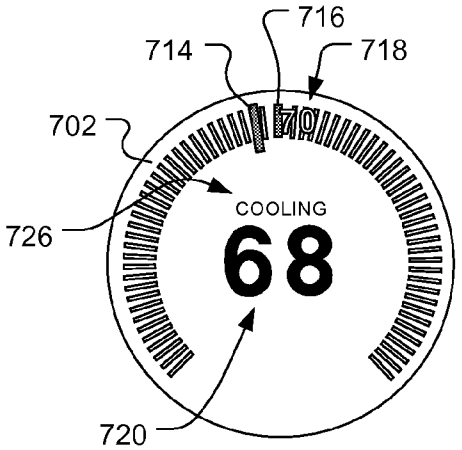

FIG. 7C

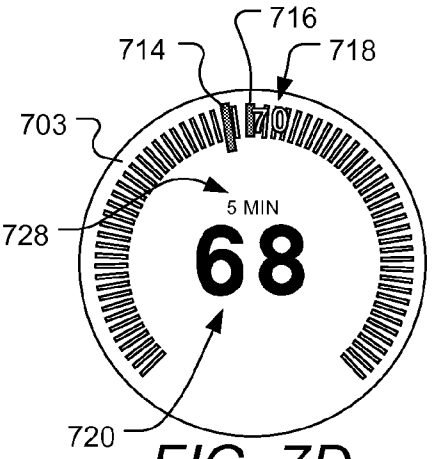

FIG. 7D

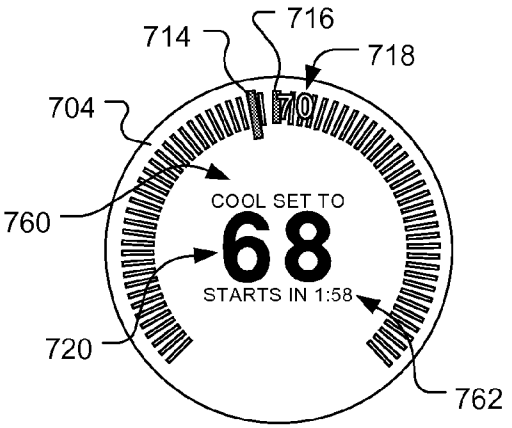

FIG. 7E

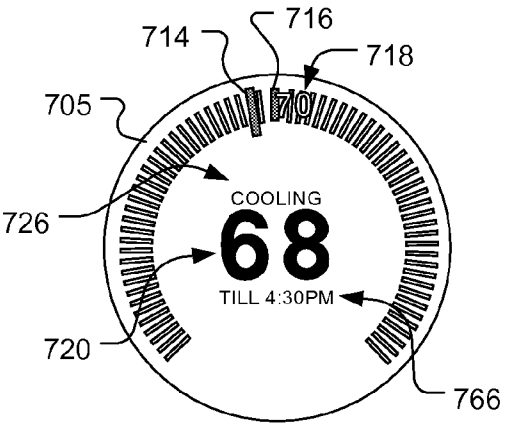

FIG. 7F

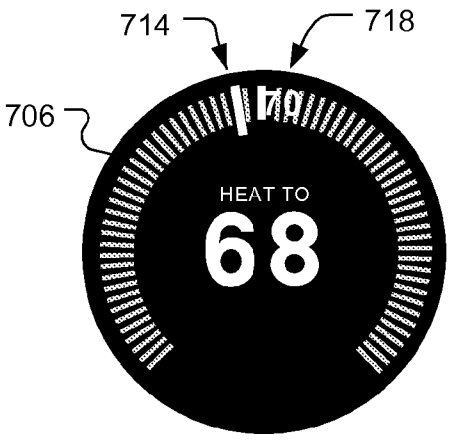

FIG. 7G

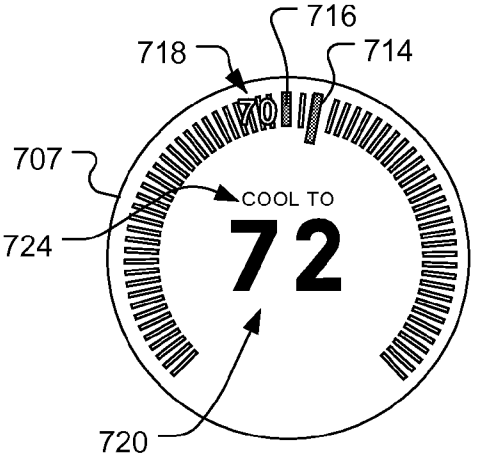

FIG. 7H

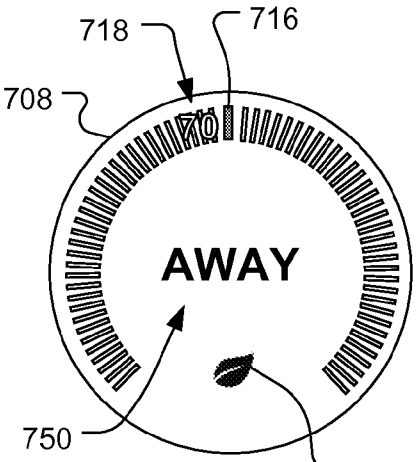

FIG. 7I

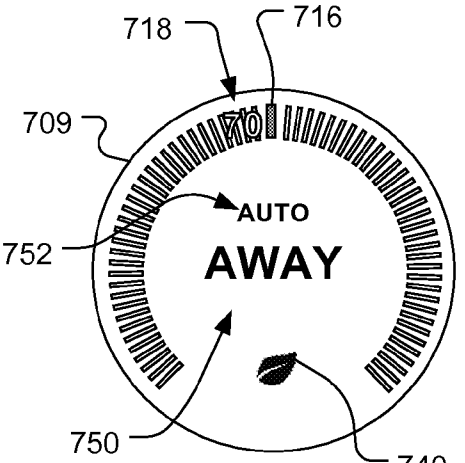

FIG. 7J

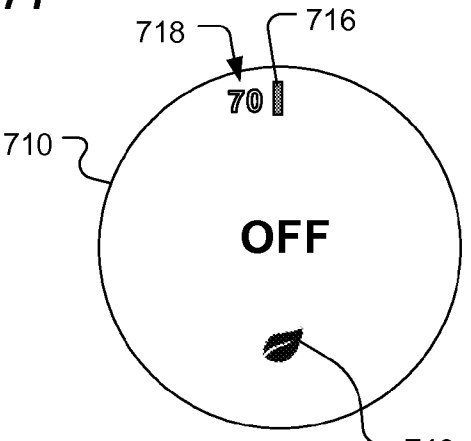

FIG. 7K

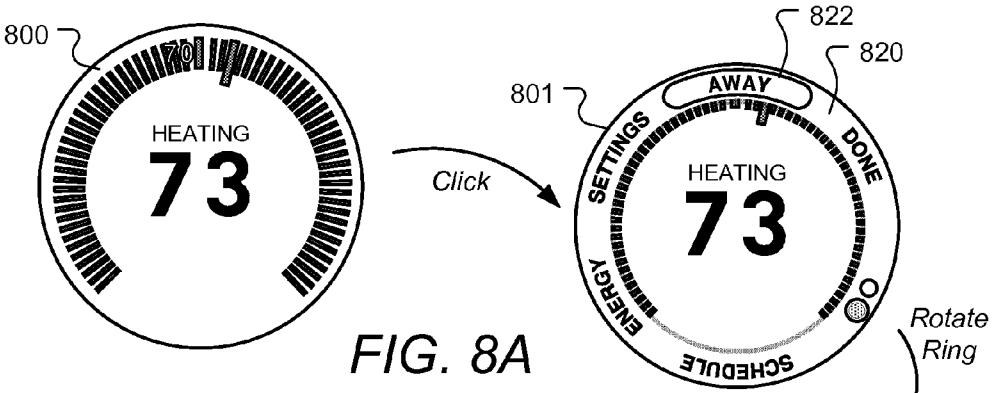

FIG. 8A

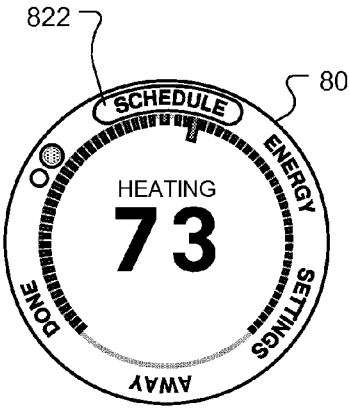

FIG. 8B

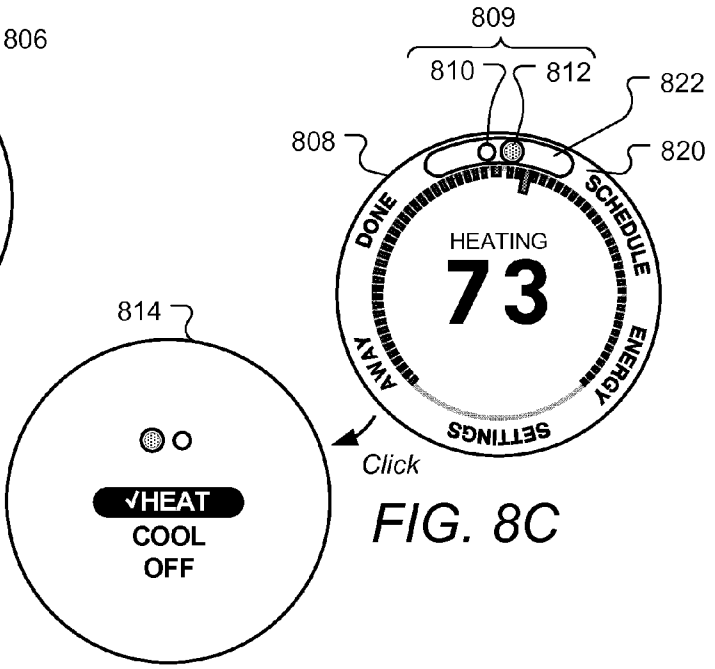

FIG. 8C

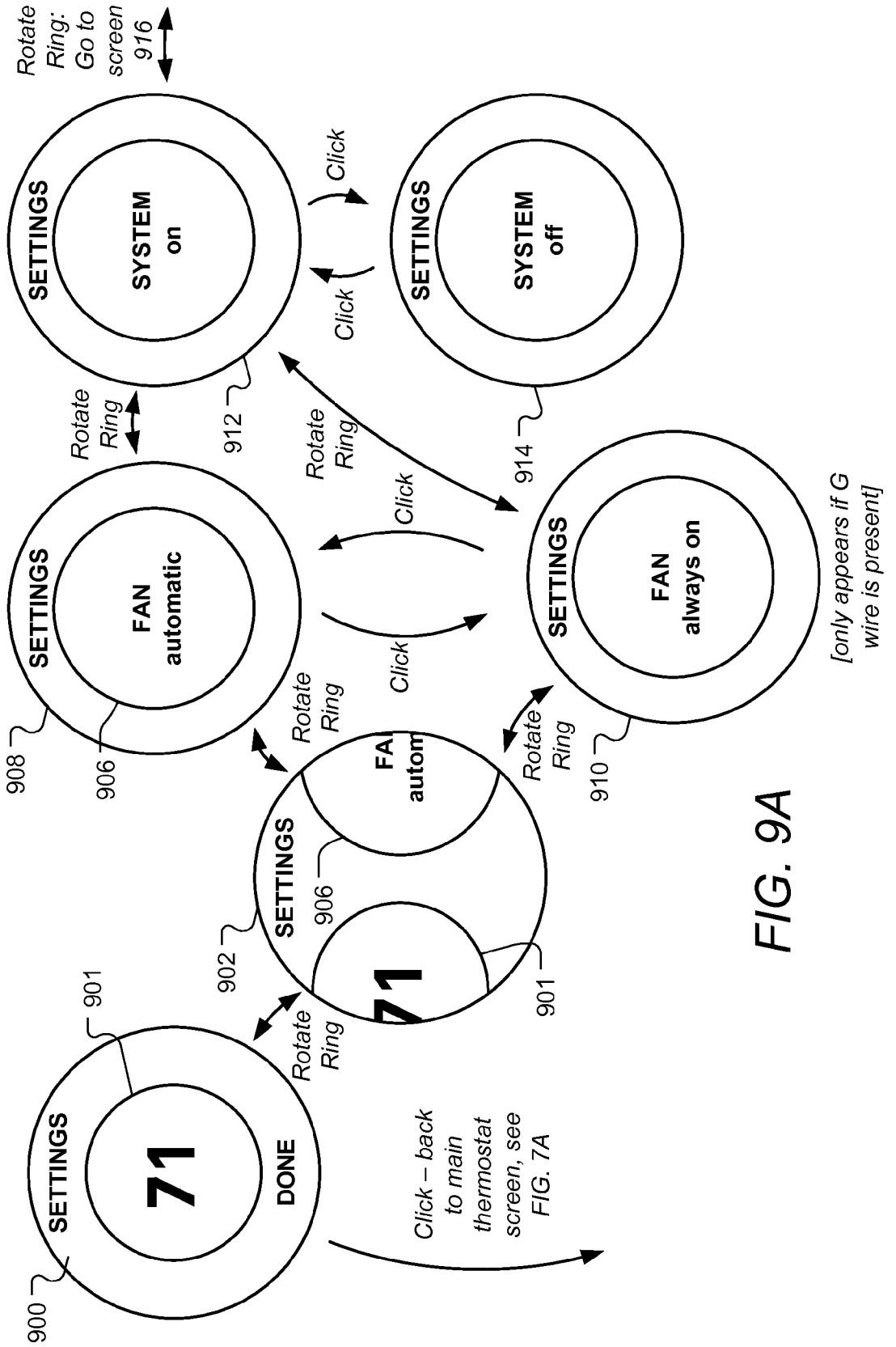
SETTINGS
71
DONE
900
901
Rotate Ring
Click – back to main thermostat screen, see FIG. 7A
SETTINGS
FA
autom
906
902
Rotate Ring
Click
SETTINGS
FAN automatic
908
906
Rotate Ring
Click
SETTINGS
FAN always on
910
[only appears if G wire is present]
Rotate Ring
Click
SETTINGS
SYSTEM on
912
Rotate Ring
Click
SETTINGS
SYSTEM off
914
Rotate Ring: Go to screen 916

FIG. 9A

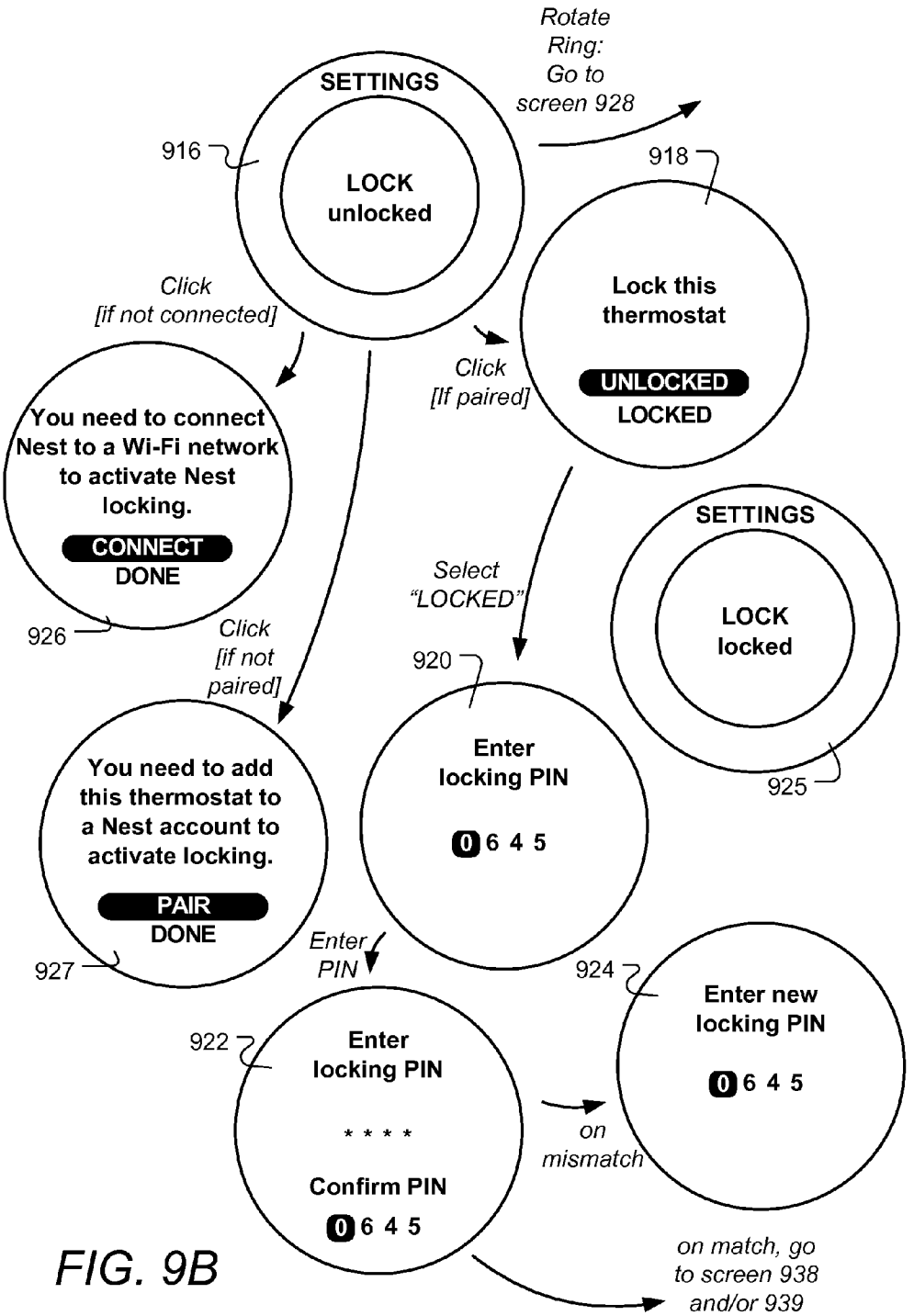
SETTINGS
LOCK
unlocked
916
Rotate
Ring:
Go to
screen 928
918
Lock this
thermostat
UNLOCKED
LOCKED
Click
[if not connected]
Click
[If paired]
You need to connect
Nest to a Wi-Fi network
to activate Nest
locking.
CONNECT
DONE
926
Click
[if not
paired]
Select
"LOCKED"
SETTINGS
LOCK
locked
925
920
Enter
locking PIN
0 6 4 5
You need to add
this thermostat to
a Nest account to
activate locking.
PAIR
DONE
927
Enter
PIN
924
Enter new
locking PIN
0 6 4 5
922
Enter
locking PIN
* * * *
Confirm PIN
0 6 4 5
on
mismatch
on match, go
to screen 938
and/or 939

FIG. 9B

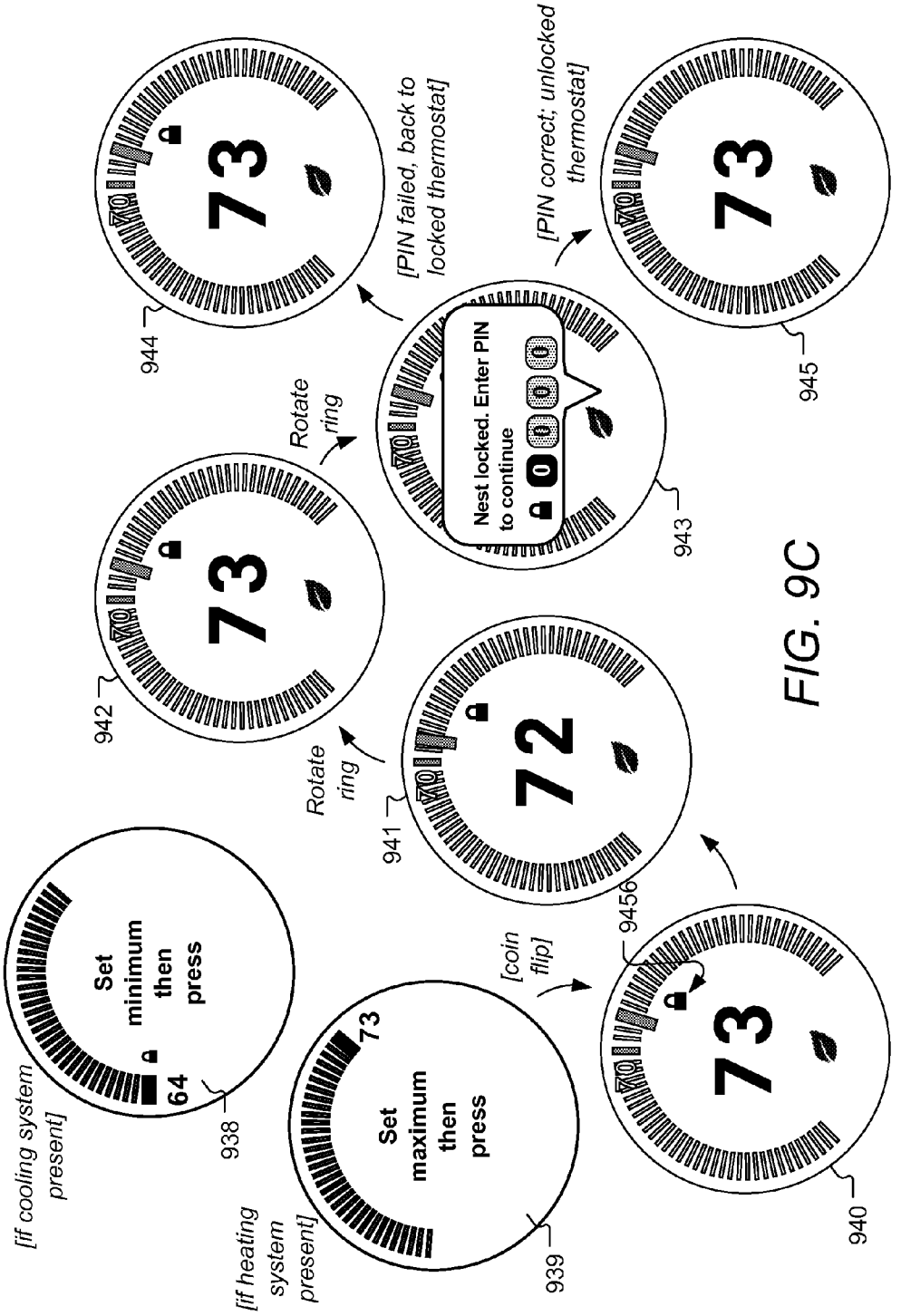
[if cooling system present]
Set minimum then press
64
938
[if heating system present]
Set maximum then press
73
939
[coin flip]
9456
73
940
941
72
Rotate ring
942
73
Rotate ring
943
Nest locked. Enter PIN to continue
0 0 0 0
[PIN failed, back to locked thermostat]
944
73
[PIN correct; unlocked thermostat]
945
73

FIG. 9C

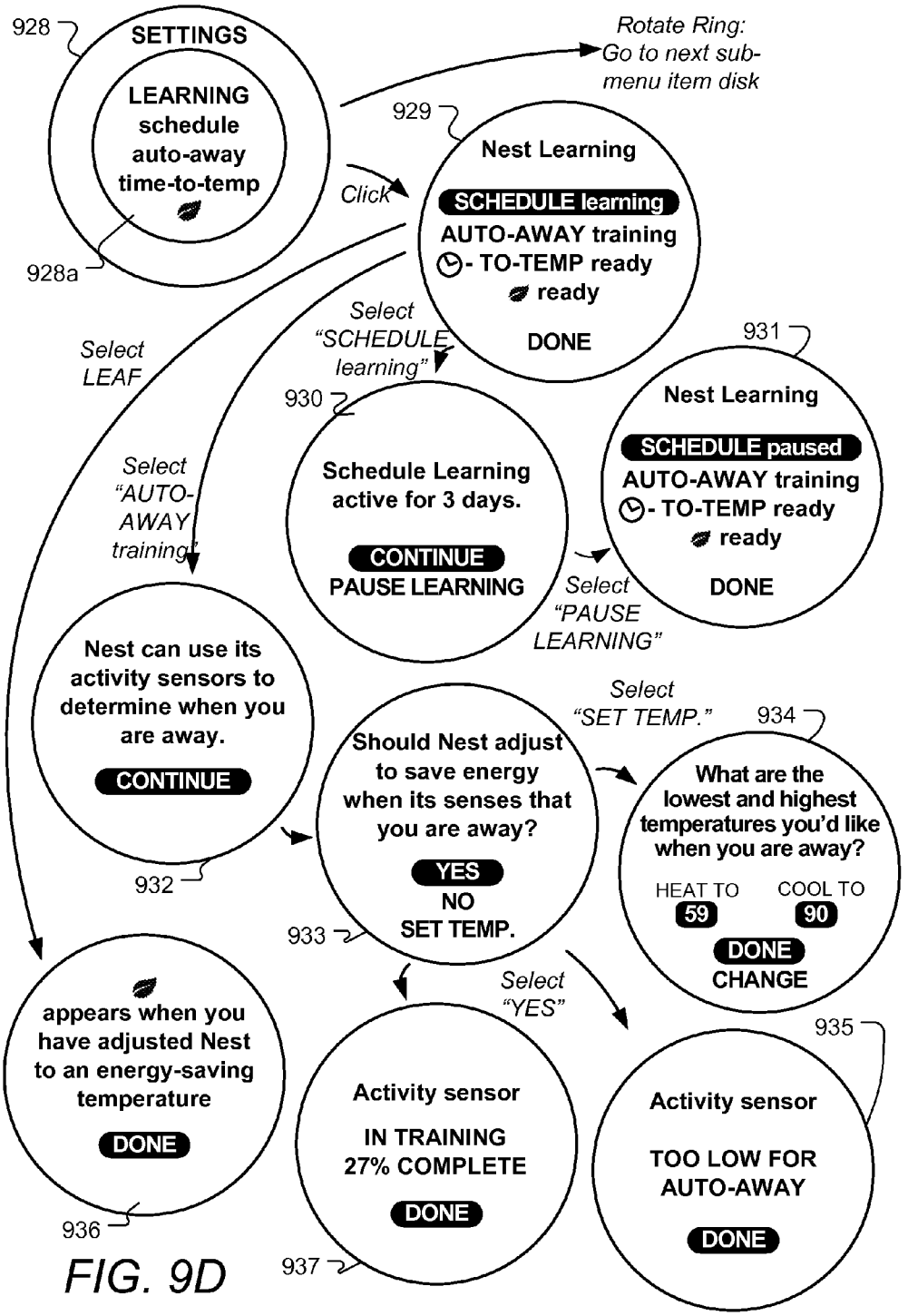
928
SETTINGS
LEARNING
schedule
auto-away
time-to-temp
928a
Rotate Ring:
Go to next sub-menu item disk
929
Nest Learning
SCHEDULE learning
AUTO-AWAY training
- TO-TEMP ready
ready
DONE
Click
Select "SCHEDULE learning"
Select LEAF
Select "AUTO-AWAY training"
930
Schedule Learning active for 3 days.
CONTINUE
PAUSE LEARNING
931
Nest Learning
SCHEDULE paused
AUTO-AWAY training
- TO-TEMP ready
ready
DONE
Select "PAUSE LEARNING"
Nest can use its activity sensors to determine when you are away.
CONTINUE
932
Select "SET TEMP."
934
Should Nest adjust to save energy when its senses that you are away?
YES
NO
SET TEMP.
933
What are the lowest and highest temperatures you'd like when you are away?
HEAT TO 59
COOL TO 90
DONE
CHANGE
appears when you have adjusted Nest to an energy-saving temperature
DONE
936
Select "YES"
Activity sensor
IN TRAINING
27% COMPLETE
DONE
937
935
Activity sensor
TOO LOW FOR AUTO-AWAY
DONE

FIG. 9D

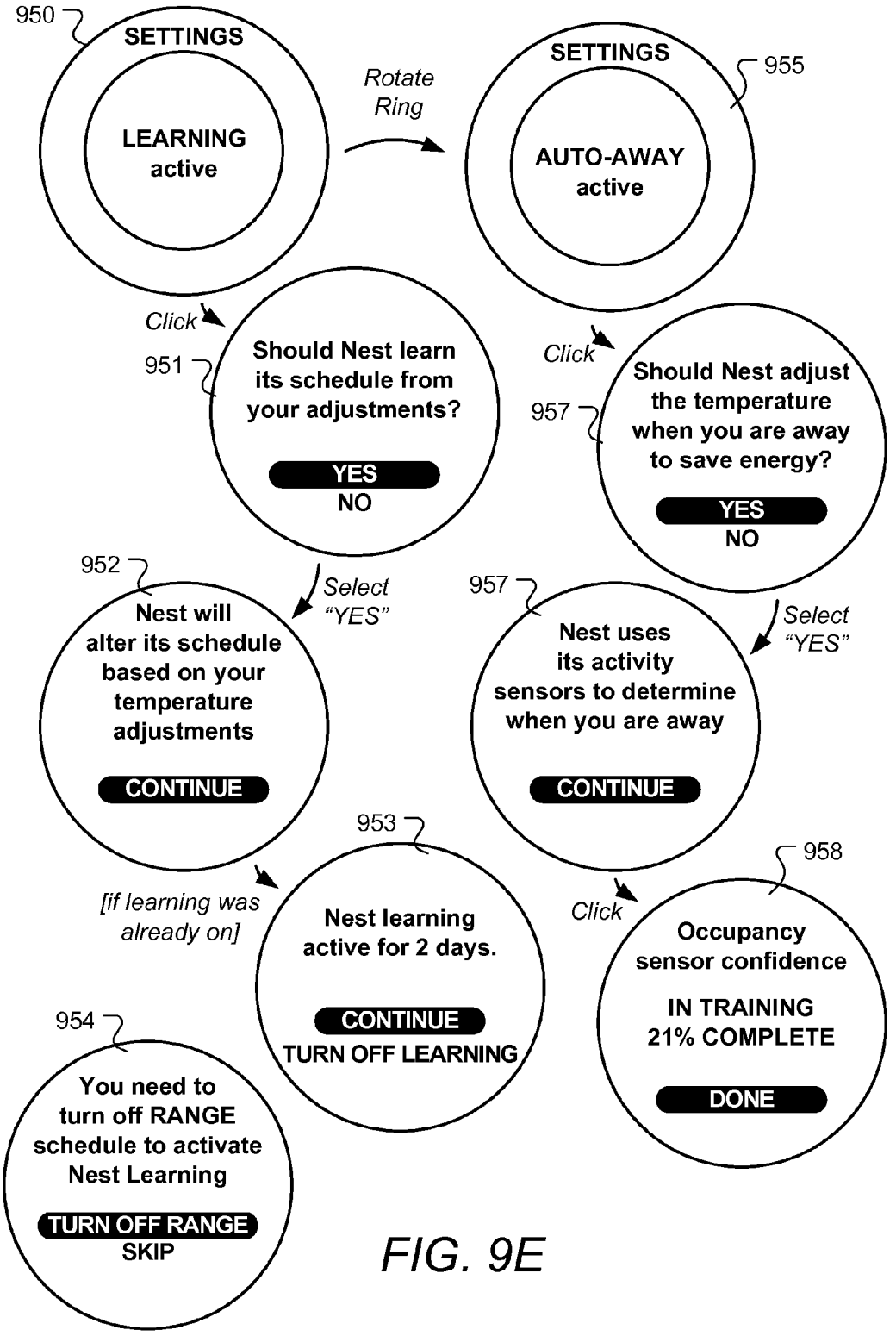
950
SETTINGS
LEARNING
active
Rotate
Ring
SETTINGS
955
AUTO-AWAY
active
Click
951
Should Nest learn its schedule from your adjustments?
YES
NO
Click
957
Should Nest adjust the temperature when you are away to save energy?
YES
NO
952
Nest will alter its schedule based on your temperature adjustments
CONTINUE
Select "YES"
957
Nest uses its activity sensors to determine when you are away
CONTINUE
Select "YES"
[if learning was already on]
953
Nest learning active for 2 days.
CONTINUE
TURN OFF LEARNING
Click
958
Occupancy sensor confidence
IN TRAINING
21% COMPLETE
DONE
954
You need to turn off RANGE schedule to activate Nest Learning
TURN OFF RANGE
SKIP

FIG. 9E

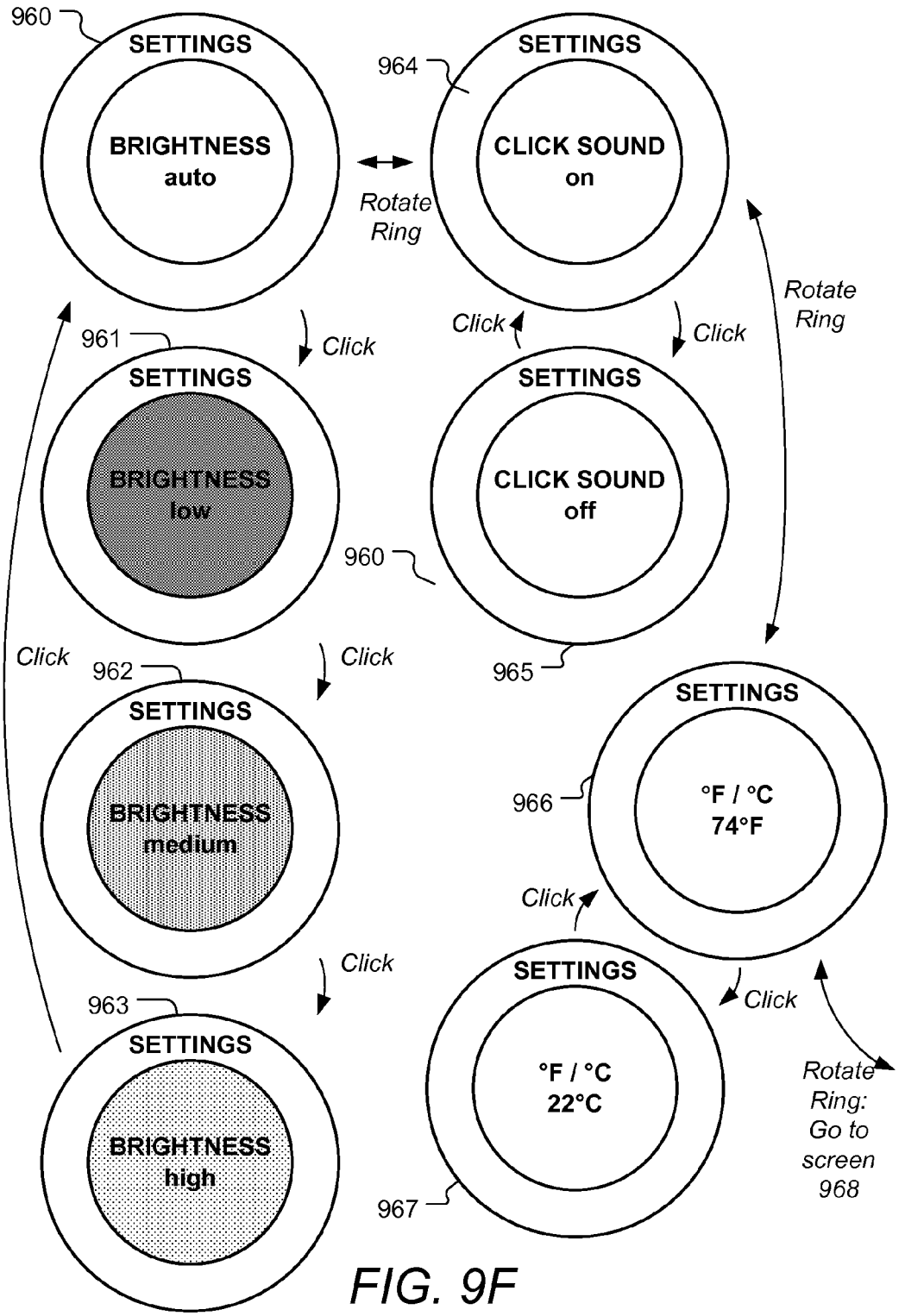
960
SETTINGS
BRIGHTNESS
auto
964
SETTINGS
CLICK SOUND
on
Rotate
Ring
Click
Click
Click
Rotate
Ring
961
SETTINGS
BRIGHTNESS
low
SETTINGS
CLICK SOUND
off
960
Click
Click
962
SETTINGS
BRIGHTNESS
medium
965
SETTINGS
°F / °C
74°F
966
Click
Click
Click
963
SETTINGS
BRIGHTNESS
high
SETTINGS
°F / °C
22°C
967
Rotate
Ring:
Go to
screen
968

FIG. 9F

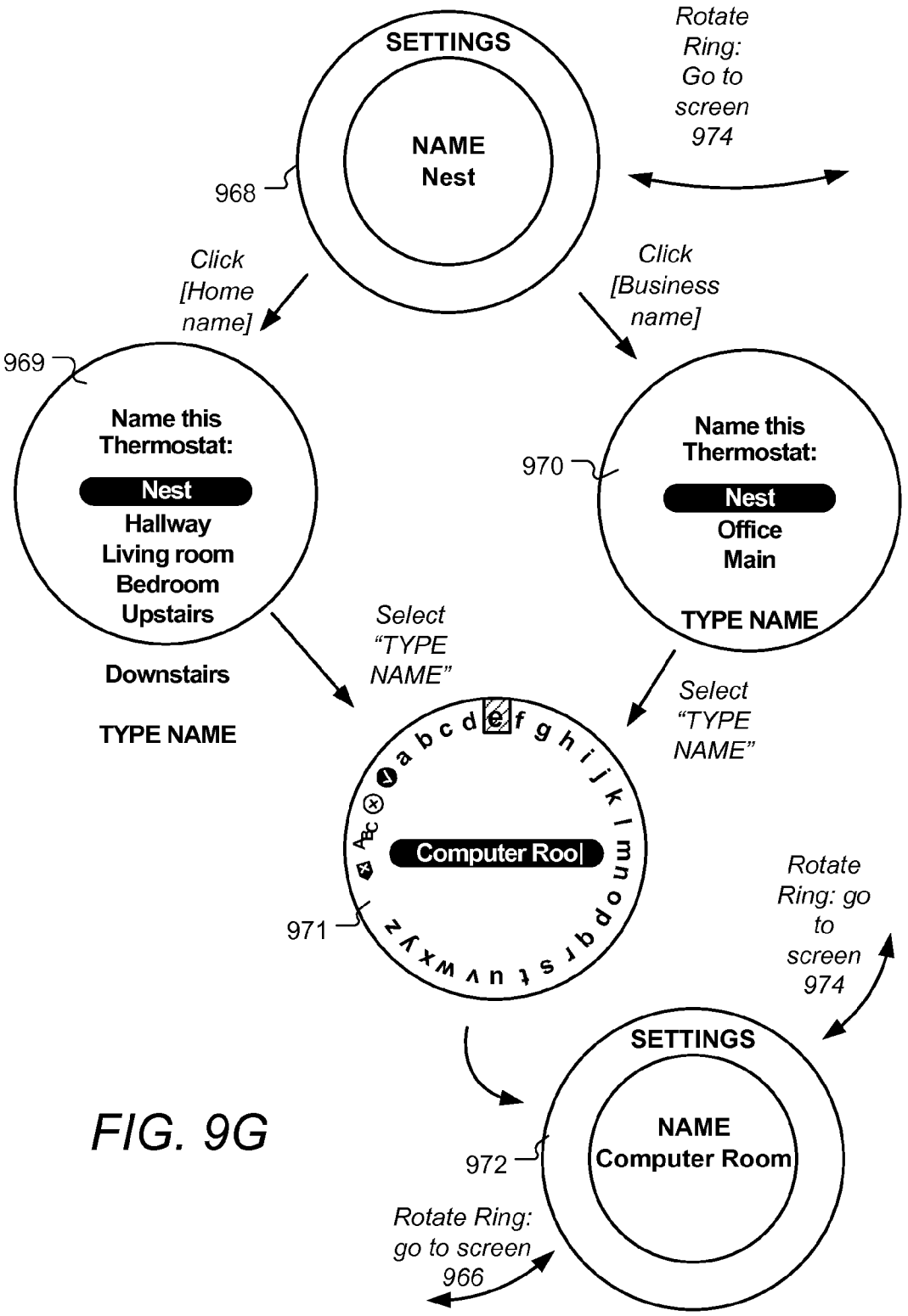
SETTINGS
NAME
Nest
968
Rotate Ring: Go to screen 974
Click [Home name]
Click [Business name]
969
Name this Thermostat:
Nest
Hallway
Living room
Bedroom
Upstairs
Downstairs
TYPE NAME
970
Name this Thermostat:
Nest
Office
Main
TYPE NAME
Select "TYPE NAME"
Select "TYPE NAME"
Computer Roo
971
Rotate Ring: go to screen 974
SETTINGS
NAME
Computer Room
972
Rotate Ring: go to screen 966

FIG. 9G

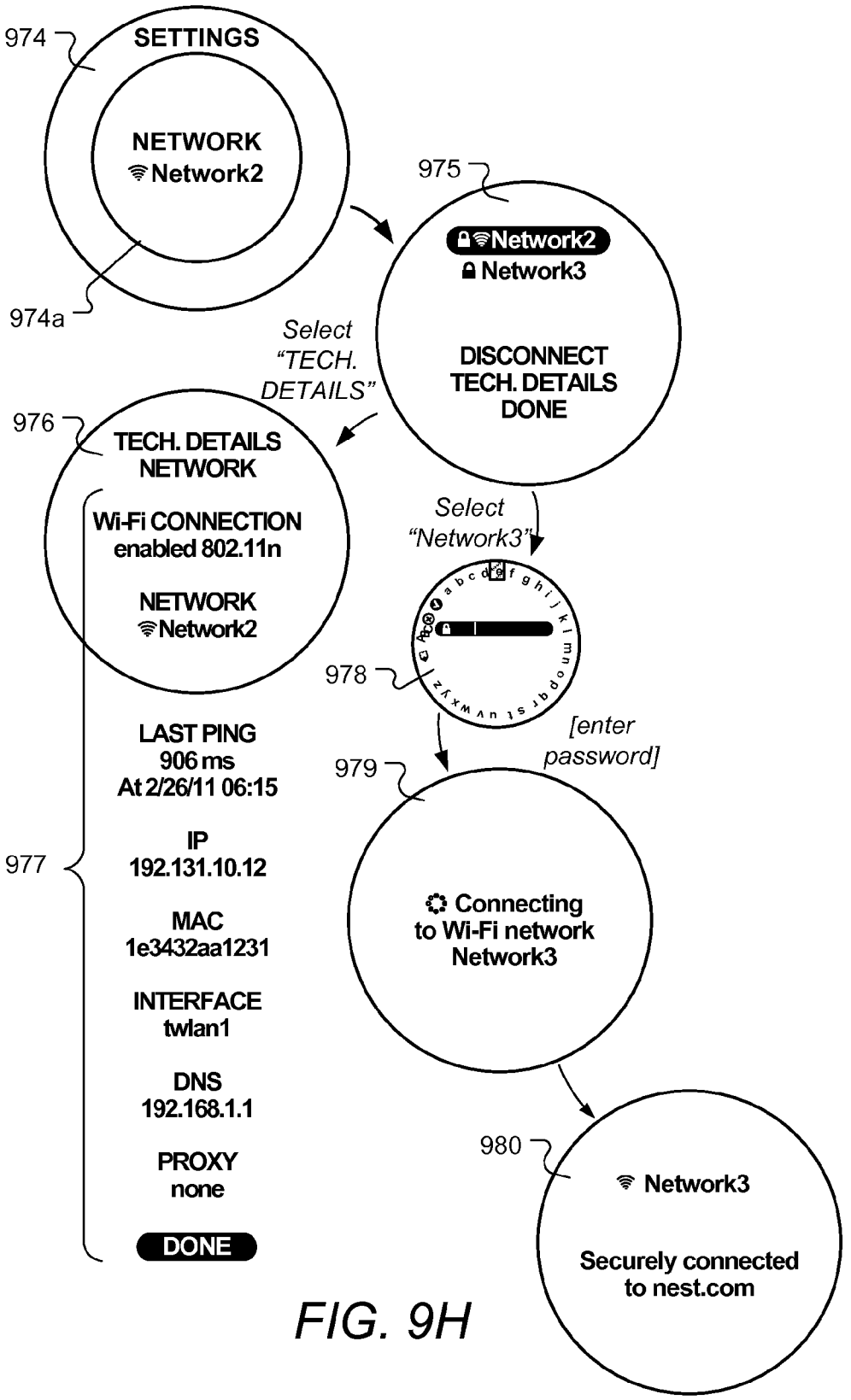
974
SETTINGS
NETWORK
Network2
974a
975
Network2
Network3
DISCONNECT
TECH. DETAILS
DONE
Select
"TECH.
DETAILS"
976
TECH. DETAILS
NETWORK
Wi-Fi CONNECTION
enabled 802.11n
NETWORK
Network2
Select
"Network3"
978
[enter
password]
979
LAST PING
906 ms
At 2/26/11 06:15
977
IP
192.131.10.12
MAC
1e3432aa1231
INTERFACE
twlan1
DNS
192.168.1.1
PROXY
none
DONE
Connecting
to Wi-Fi network
Network3
980
Network3
Securely connected
to nest.com

FIG. 9H

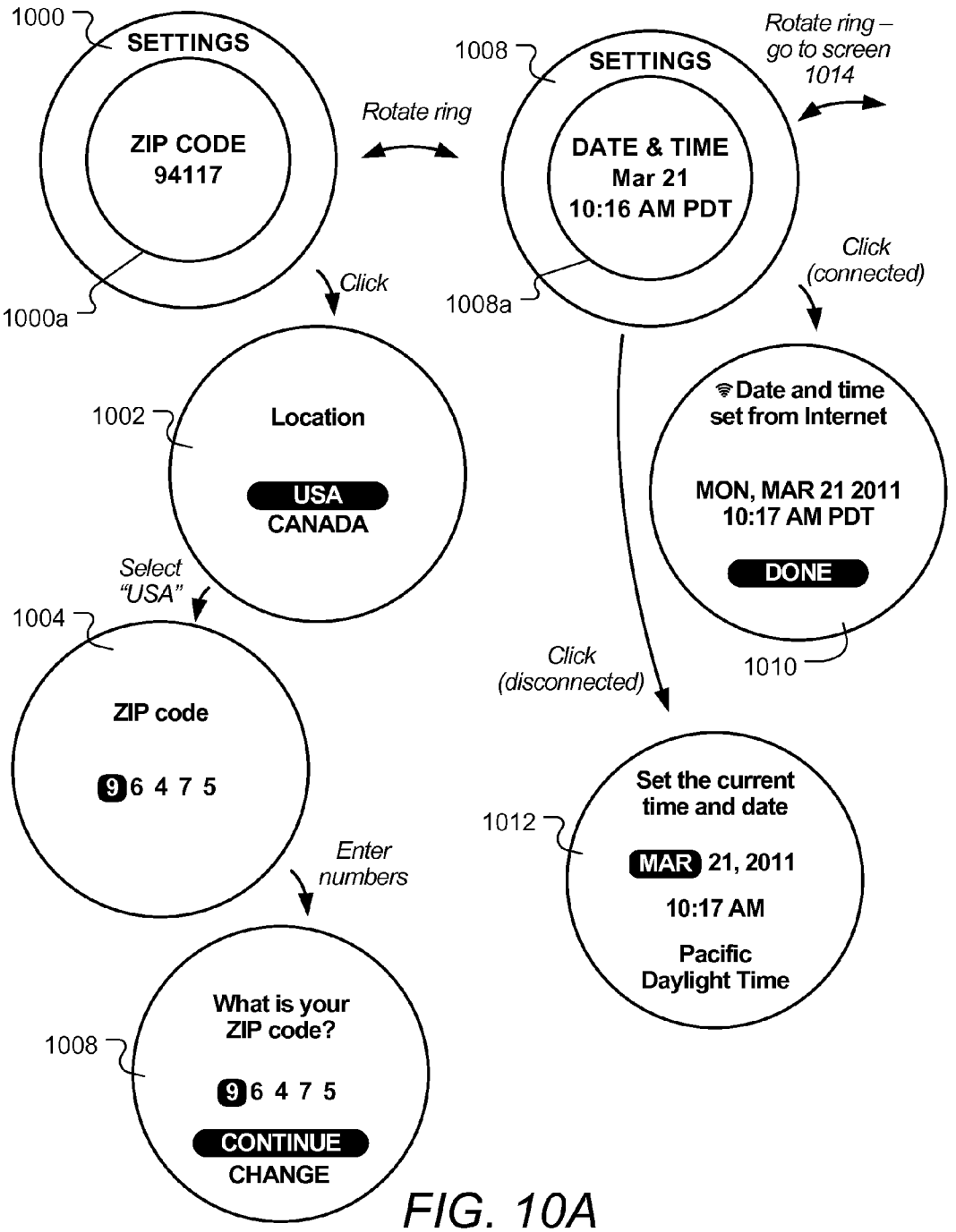
1000
SETTINGS
ZIP CODE
94117
1000a
Rotate ring
1008
SETTINGS
DATE & TIME
Mar 21
10:16 AM PDT
1008a
Rotate ring – go to screen 1014
Click
Click (connected)
1002
Location
USA
CANADA
Select "USA"
1004
ZIP code
9 6 4 7 5
Enter numbers
1008
What is your ZIP code?
9 6 4 7 5
CONTINUE
CHANGE
Date and time set from Internet
MON, MAR 21 2011
10:17 AM PDT
DONE
1010
Click (disconnected)
1012
Set the current time and date
MAR 21, 2011
10:17 AM
Pacific Daylight Time

FIG. 10A

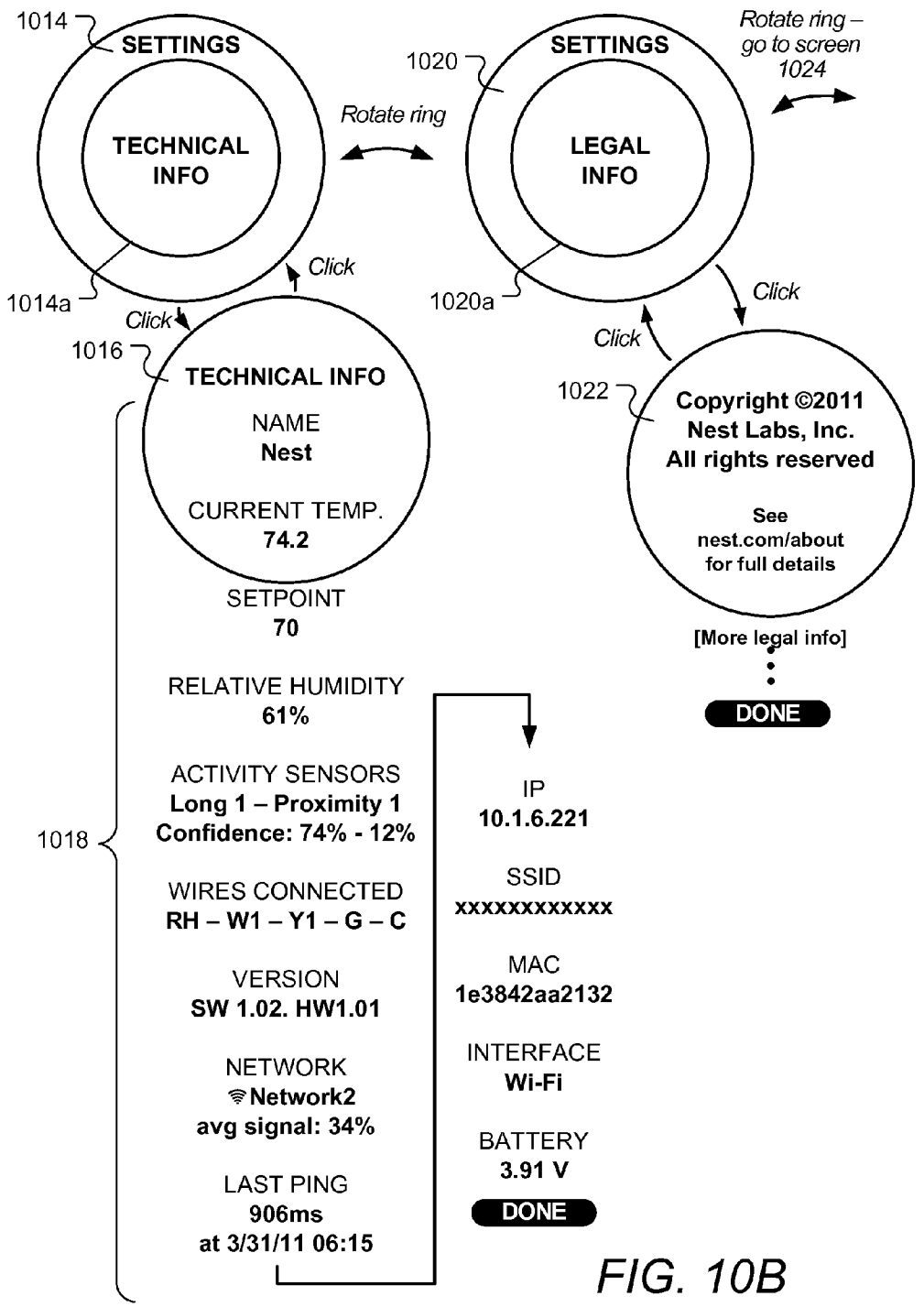
1014
SETTINGS
TECHNICAL INFO
Rotate ring
1020
SETTINGS
LEGAL INFO
Rotate ring – go to screen 1024
Click
1014a
Click
1020a
Click
Click
1016
TECHNICAL INFO
NAME
Nest
CURRENT TEMP.
74.2
SETPOINT
70
RELATIVE HUMIDITY
61%
ACTIVITY SENSORS
Long 1 – Proximity 1
Confidence: 74% - 12%
WIRES CONNECTED
RH – W1 – Y1 – G – C
VERSION
SW 1.02. HW1.01
NETWORK
Network2
avg signal: 34%
LAST PING
906ms
at 3/31/11 06:15
1018
IP
10.1.6.221
SSID
xxxxxxxxxxxx
MAC
1e3842aa2132
INTERFACE
Wi-Fi
BATTERY
3.91 V
DONE
1022
Copyright ©2011
Nest Labs, Inc.
All rights reserved
See
nest.com/about
for full details
[More legal info]
DONE

FIG. 10B

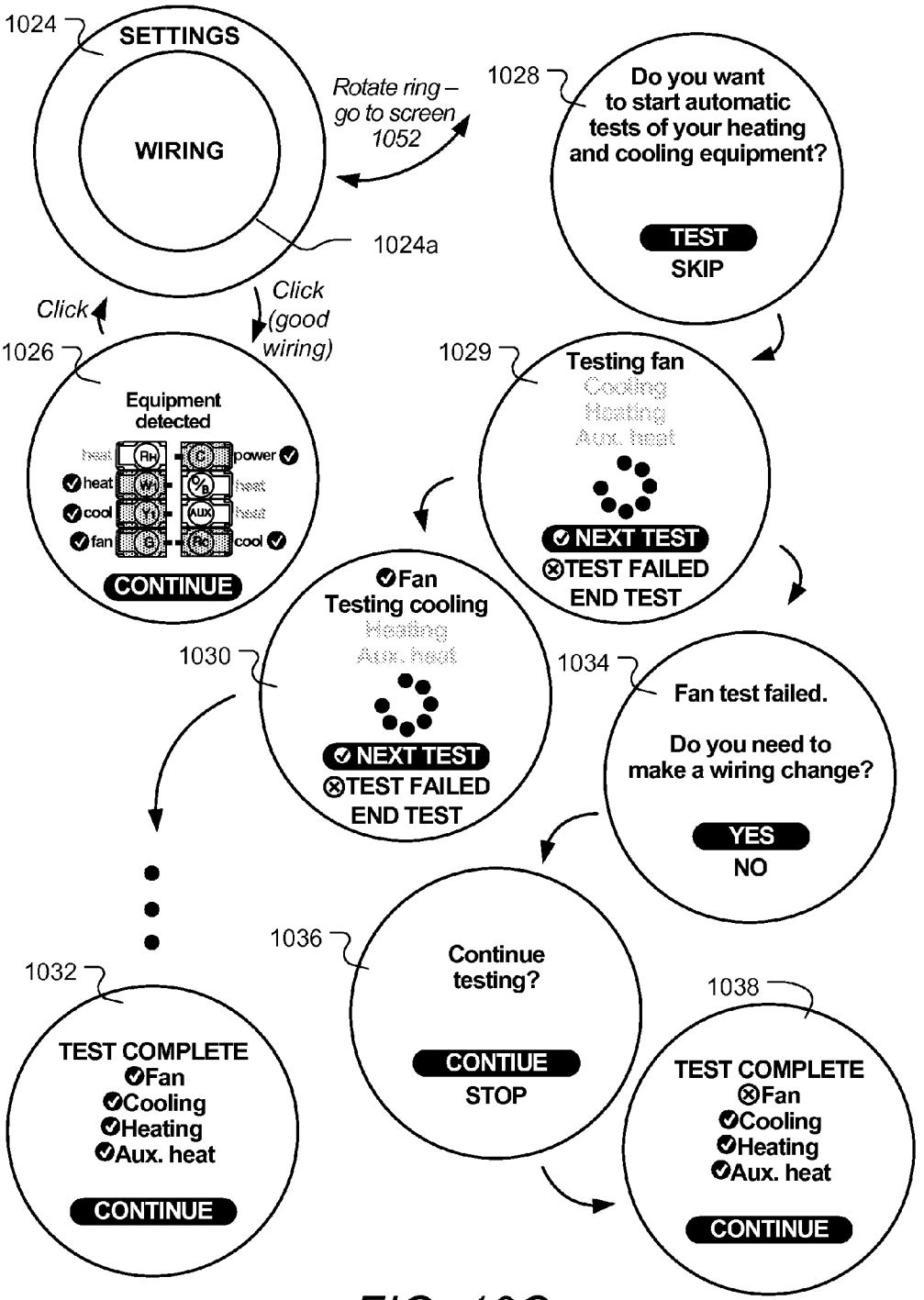
1024
SETTINGS
WIRING
Rotate ring – go to screen 1052
1024a
1028
Do you want to start automatic tests of your heating and cooling equipment?
TEST
SKIP
Click
Click (good wiring)
1026
Equipment detected
heat
cool
fan
power
heat
cool
CONTINUE
1029
Testing fan
Cooling
Heating
Aux. heat
NEXT TEST
TEST FAILED
END TEST
Fan
Testing cooling
Heating
Aux. heat
1030
NEXT TEST
TEST FAILED
END TEST
1034
Fan test failed.
Do you need to make a wiring change?
YES
NO
1032
TEST COMPLETE
Fan
Cooling
Heating
Aux. heat
CONTINUE
1036
Continue testing?
CONTIUE
STOP
1038
TEST COMPLETE
Fan
Cooling
Heating
Aux. heat
CONTINUE

FIG. 10C

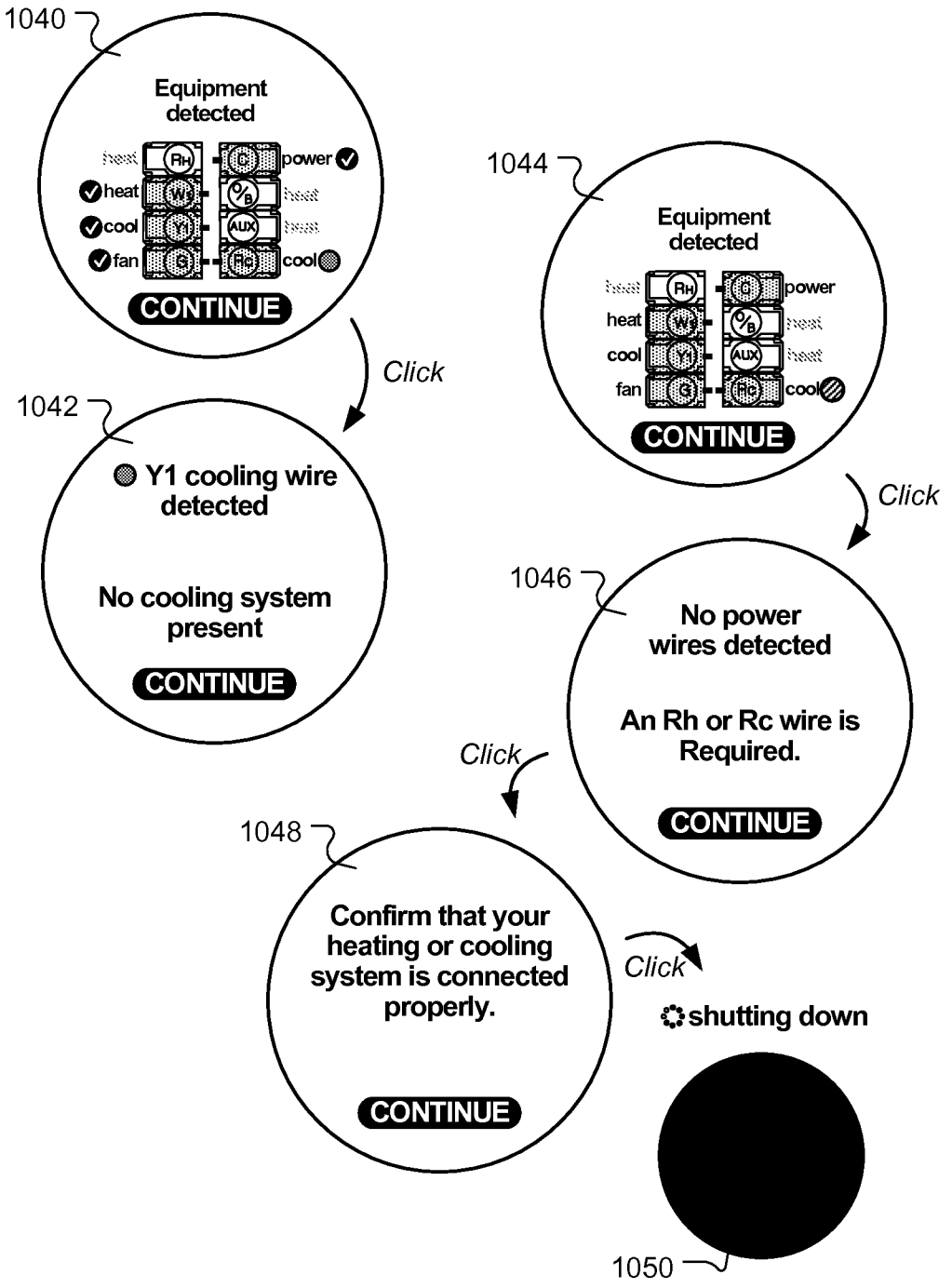
1040
Equipment detected
heat
power
heat
cool
fan
cool
CONTINUE
Click
1042
Y1 cooling wire detected
No cooling system present
CONTINUE
1044
Equipment detected
power
heat
heat
cool
heat
fan
cool
CONTINUE
Click
1046
No power wires detected
An Rh or Rc wire is Required.
CONTINUE
Click
1048
Confirm that your heating or cooling system is connected properly.
CONTINUE
Click
shutting down
1050

FIG. 10D

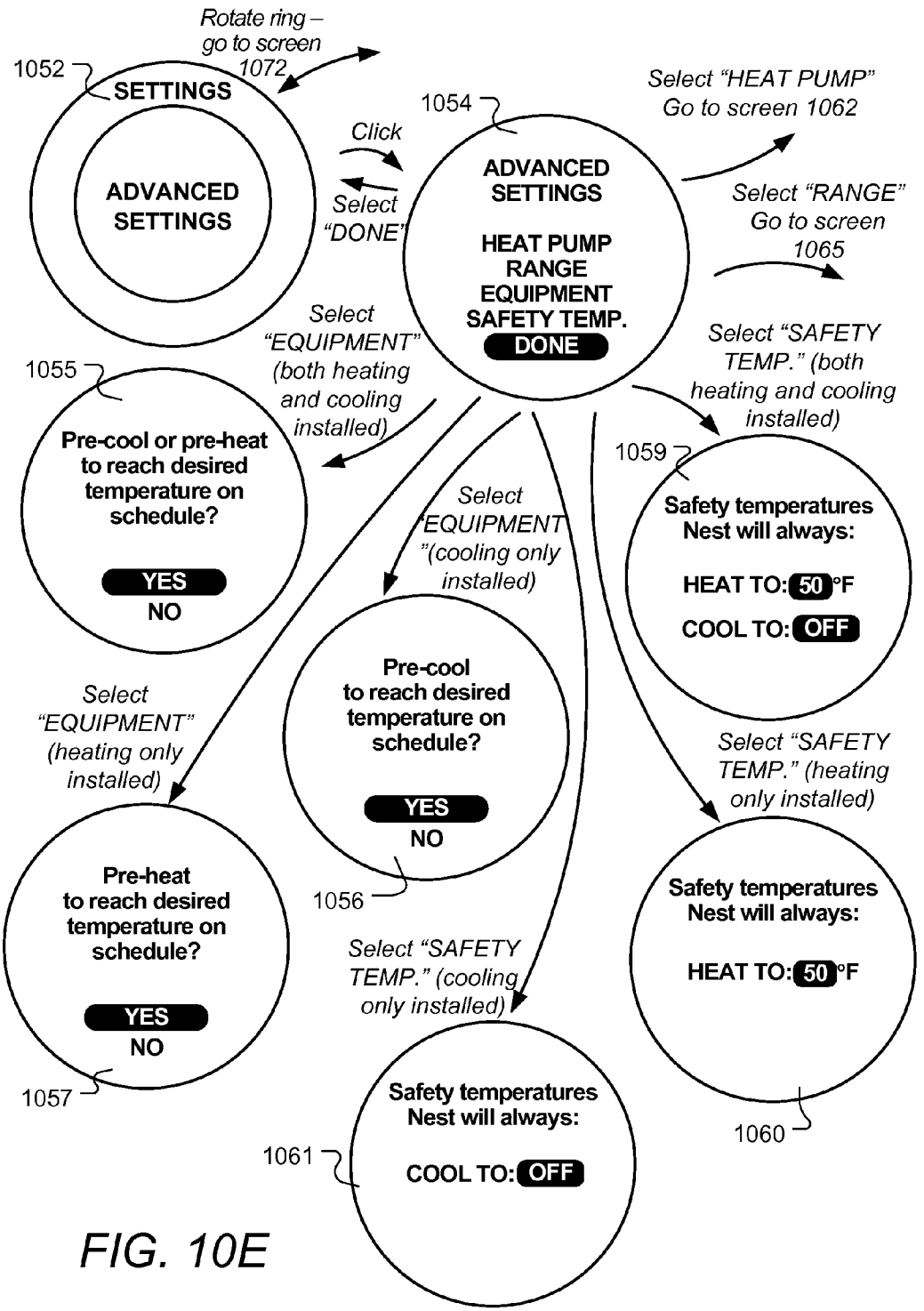
Rotate ring – go to screen 1072
1052
SETTINGS
ADVANCED SETTINGS
Click
Select "DONE"
1054
ADVANCED SETTINGS
HEAT PUMP
RANGE
EQUIPMENT
SAFETY TEMP.
DONE
Select "HEAT PUMP" Go to screen 1062
Select "RANGE" Go to screen 1065
Select "EQUIPMENT" (both heating and cooling installed)
Select "SAFETY TEMP." (both heating and cooling installed)
1055
Pre-cool or pre-heat to reach desired temperature on schedule?
YES
NO
1059
Safety temperatures Nest will always:
HEAT TO: 50 °F
COOL TO: OFF
Select "EQUIPMENT "(cooling only installed)
Pre-cool to reach desired temperature on schedule?
YES
NO
1056
Select "EQUIPMENT" (heating only installed)
Select "SAFETY TEMP." (heating only installed)
Pre-heat to reach desired temperature on schedule?
YES
NO
1057
Safety temperatures Nest will always:
HEAT TO: 50 °F
1060
Select "SAFETY TEMP." (cooling only installed)
Safety temperatures Nest will always:
COOL TO: OFF
1061

FIG. 10E

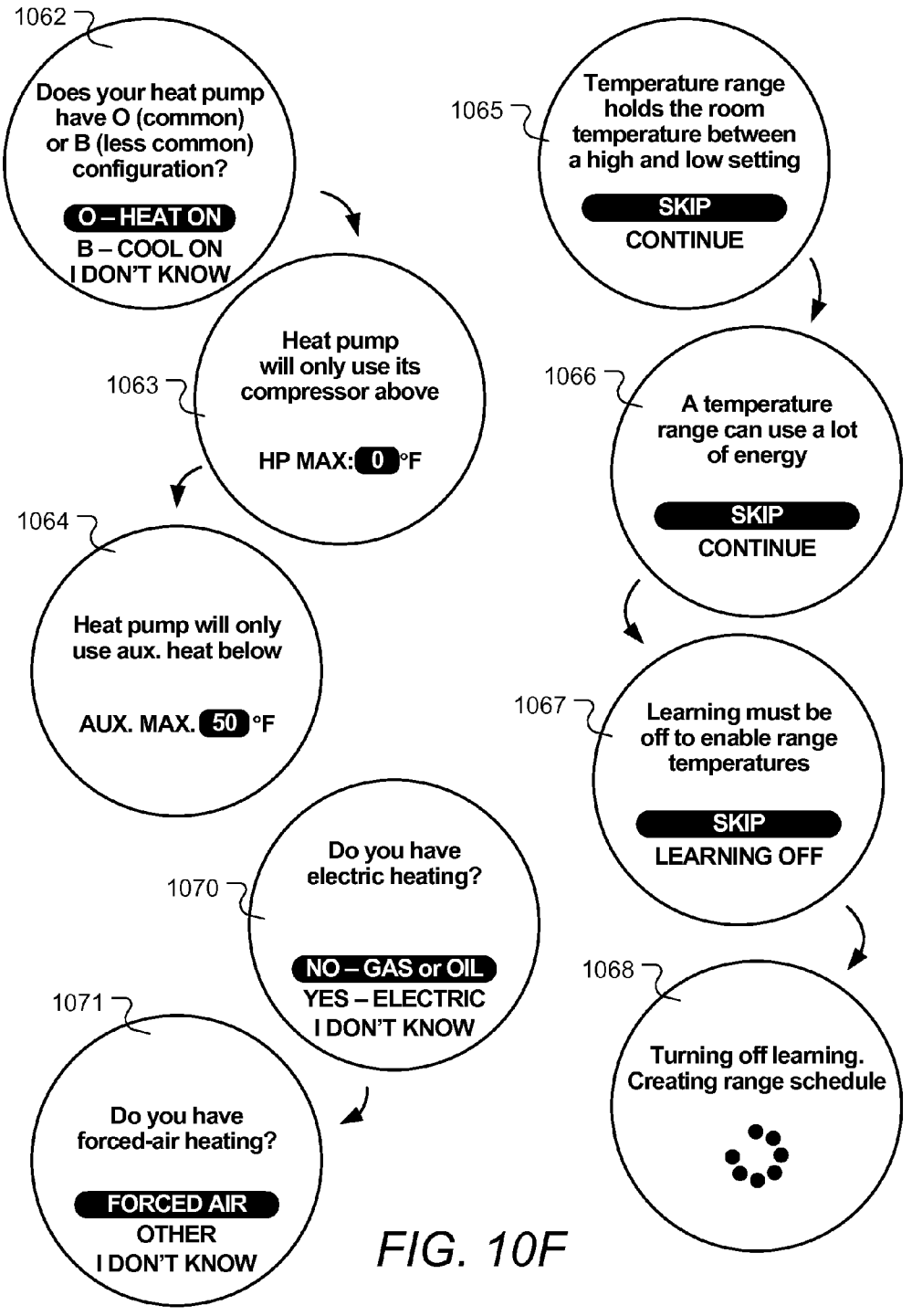
1062
Does your heat pump have O (common) or B (less common) configuration?
O – HEAT ON
B – COOL ON
I DON'T KNOW
1063
Heat pump will only use its compressor above
HP MAX: 0 °F
1064
Heat pump will only use aux. heat below
AUX. MAX. 50 °F
1065
Temperature range holds the room temperature between a high and low setting
SKIP
CONTINUE
1066
A temperature range can use a lot of energy
SKIP
CONTINUE
1067
Learning must be off to enable range temperatures
SKIP
LEARNING OFF
1068
Turning off learning. Creating range schedule
1070
Do you have electric heating?
NO – GAS or OIL
YES – ELECTRIC
I DON'T KNOW
1071
Do you have forced-air heating?
FORCED AIR
OTHER
I DON'T KNOW

FIG. 10F

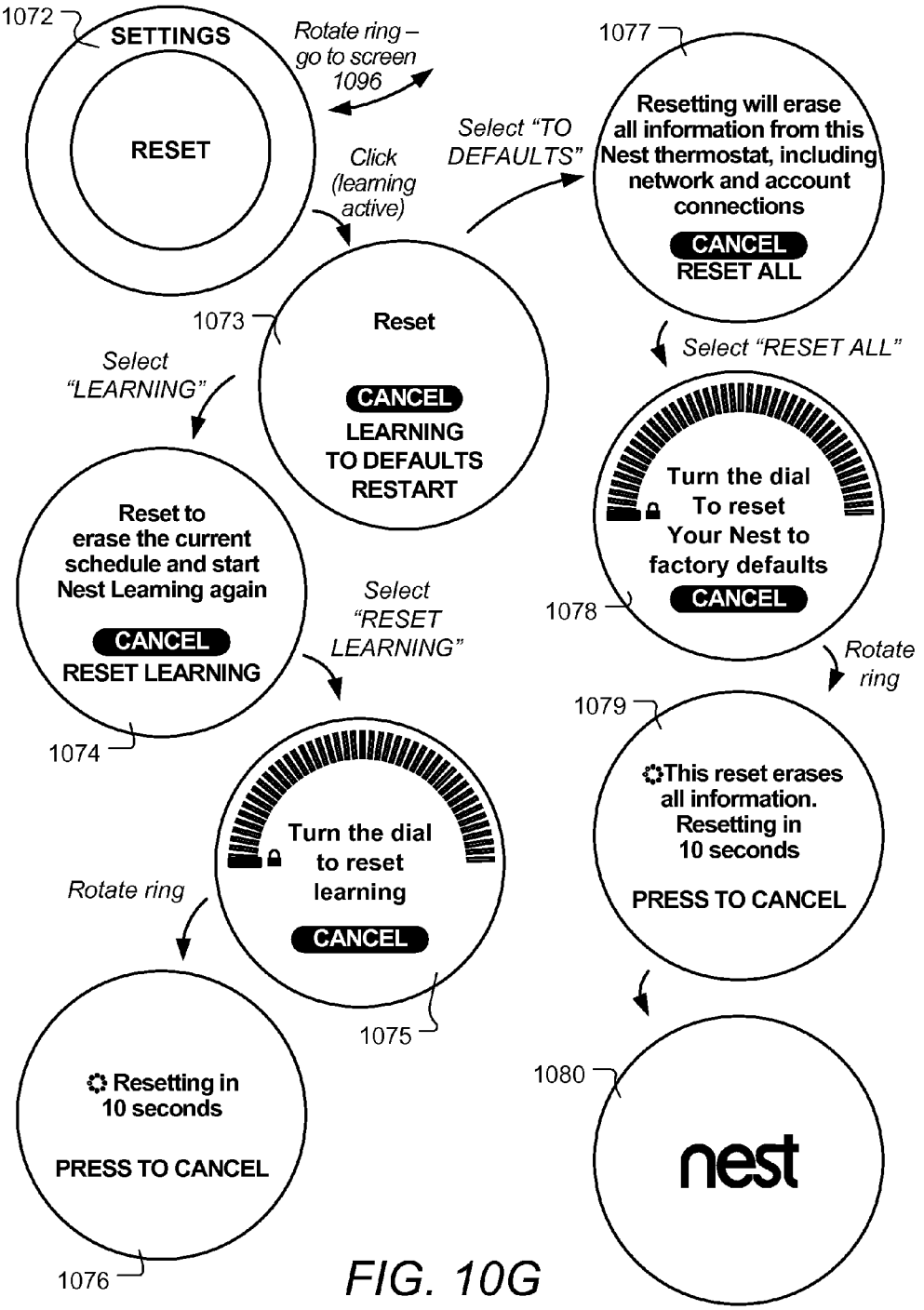
1072
SETTINGS
RESET
Rotate ring – go to screen 1096
Click (learning active)
Select "TO DEFAULTS"
1077
Resetting will erase all information from this Nest thermostat, including network and account connections
CANCEL
RESET ALL
1073
Reset
CANCEL
LEARNING
TO DEFAULTS
RESTART
Select "LEARNING"
Select "RESET ALL"
Reset to erase the current schedule and start Nest Learning again
CANCEL
RESET LEARNING
1074
Select "RESET LEARNING"
Turn the dial To reset Your Nest to factory defaults
CANCEL
1078
Rotate ring
1079
This reset erases all information. Resetting in 10 seconds
PRESS TO CANCEL
Turn the dial to reset learning
CANCEL
1075
Rotate ring
Resetting in 10 seconds
PRESS TO CANCEL
1076
1080
nest

FIG. 10G

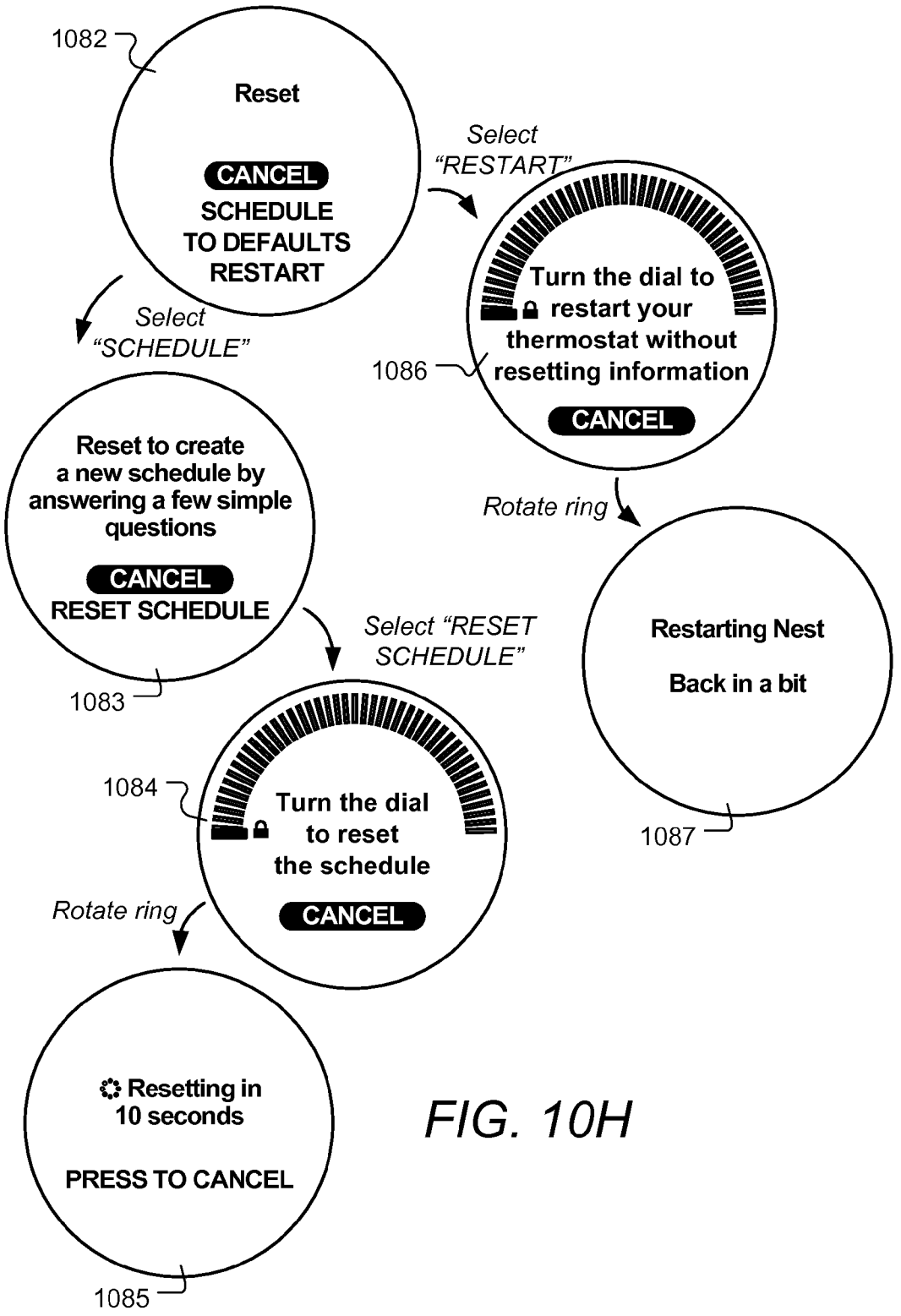
1082
Reset
CANCEL
SCHEDULE
TO DEFAULTS
RESTART
Select
"RESTART"
Select
"SCHEDULE"
Turn the dial to
restart your
thermostat without
resetting information
1086
CANCEL
Reset to create
a new schedule by
answering a few simple
questions
CANCEL
RESET SCHEDULE
1083
Rotate ring
Restarting Nest
Back in a bit
1087
Select "RESET
SCHEDULE"
1084
Turn the dial
to reset
the schedule
CANCEL
Rotate ring
Resetting in
10 seconds
PRESS TO CANCEL
1085

FIG. 10H

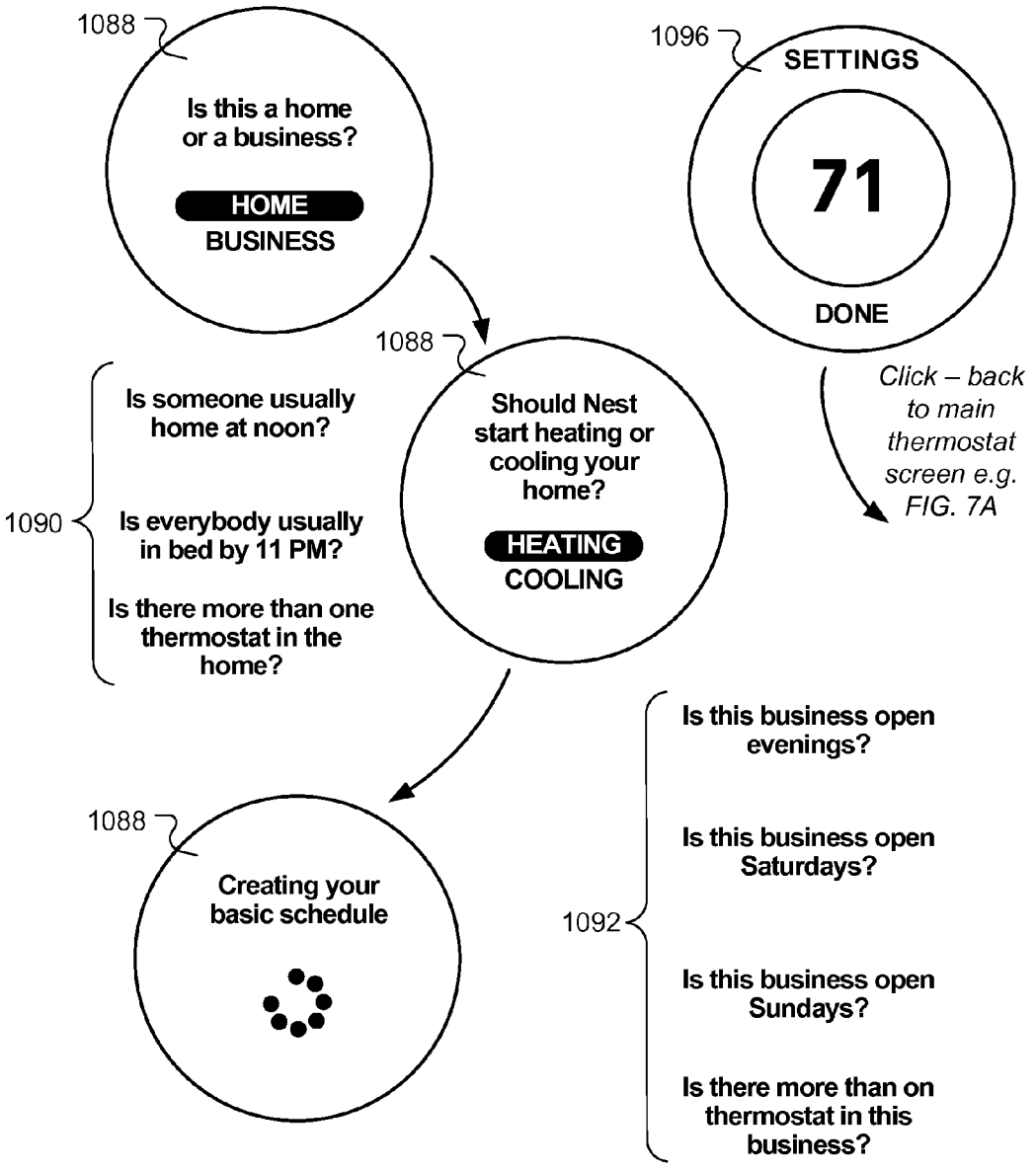
1088
Is this a home or a business?
HOME
BUSINESS
1096
SETTINGS
71
DONE
Click – back to main thermostat screen e.g. FIG. 7A
1088
Should Nest start heating or cooling your home?
HEATING
COOLING
1090
Is someone usually home at noon?
Is everybody usually in bed by 11 PM?
Is there more than one thermostat in the home?
1088
Creating your basic schedule
1092
Is this business open evenings?
Is this business open Saturdays?
Is this business open Sundays?
Is there more than on thermostat in this business?

FIG. 10I

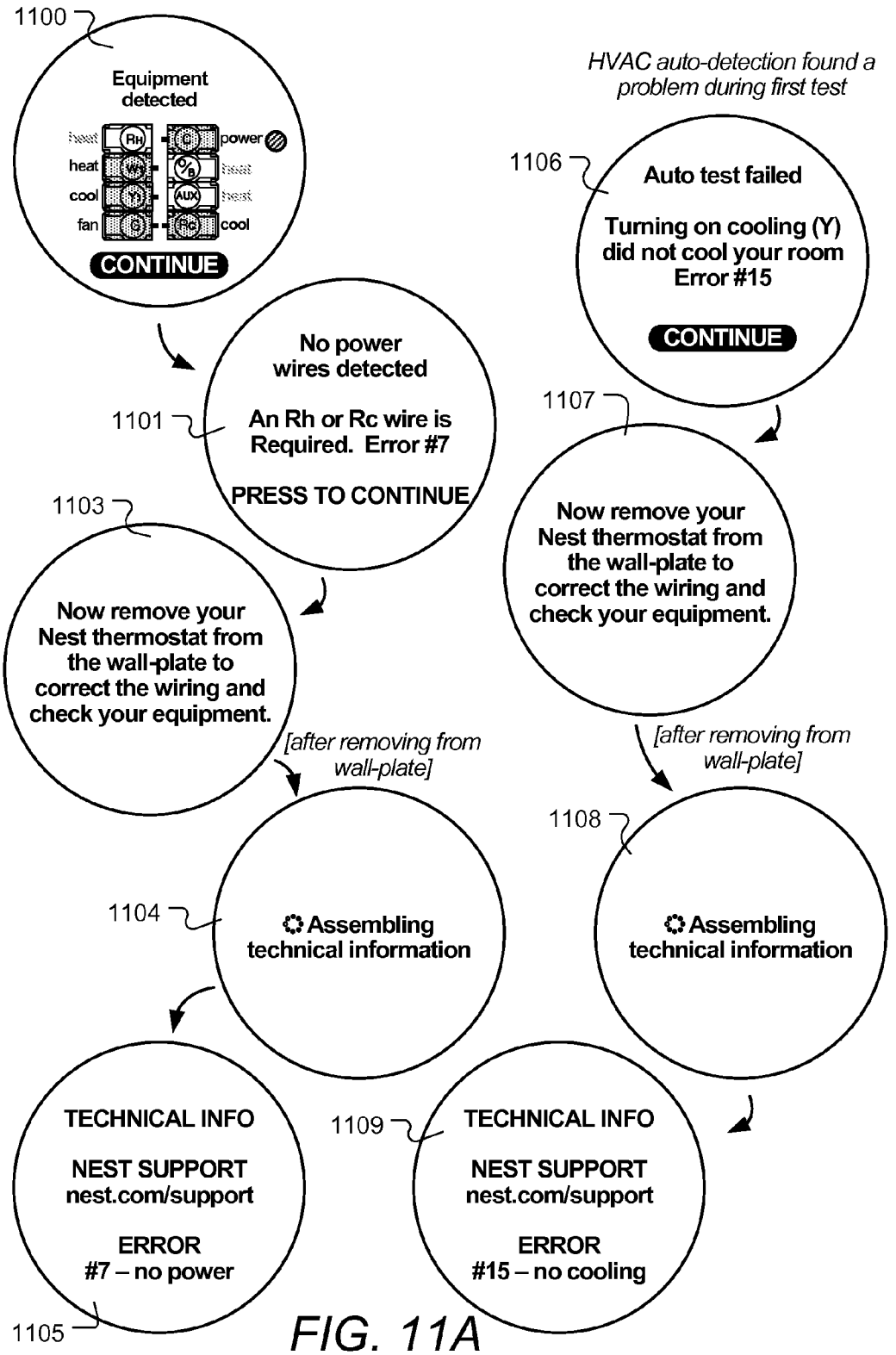
1100
Equipment detected
power
heat
cool
fan
CONTINUE
No power wires detected
1101
An Rh or Rc wire is Required. Error #7
PRESS TO CONTINUE
1103
Now remove your Nest thermostat from the wall-plate to correct the wiring and check your equipment.
[after removing from wall-plate]
1104
Assembling technical information
TECHNICAL INFO
NEST SUPPORT
nest.com/support
ERROR
#7 – no power
1105
HVAC auto-detection found a problem during first test
1106
Auto test failed
Turning on cooling (Y) did not cool your room
Error #15
CONTINUE
1107
Now remove your Nest thermostat from the wall-plate to correct the wiring and check your equipment.
[after removing from wall-plate]
1108
Assembling technical information
1109
TECHNICAL INFO
NEST SUPPORT
nest.com/support
ERROR
#15 – no cooling

FIG. 11A

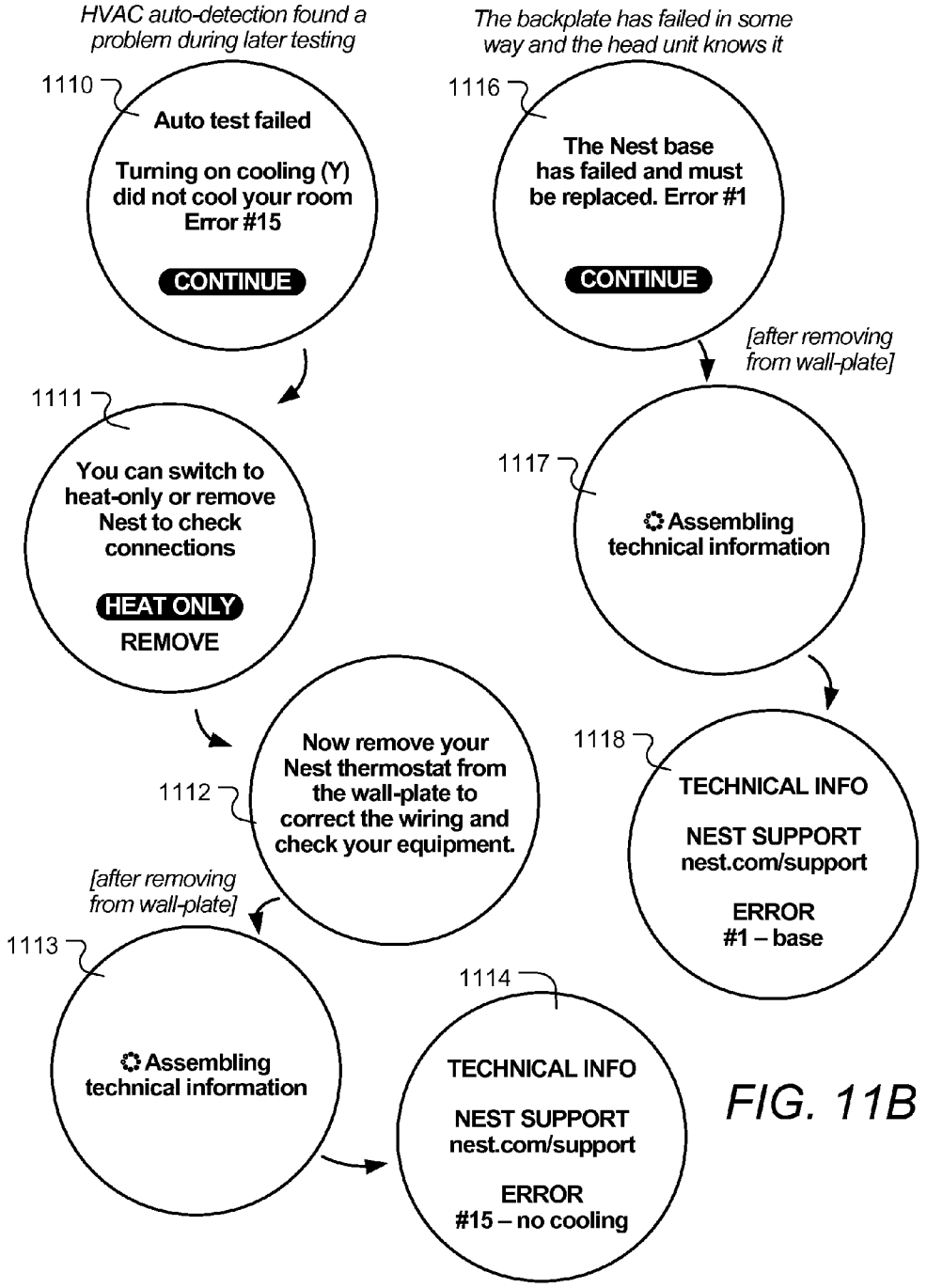
HVAC auto-detection found a problem during later testing
1110
Auto test failed
Turning on cooling (Y) did not cool your room
Error #15
CONTINUE
1111
You can switch to heat-only or remove Nest to check connections
HEAT ONLY
REMOVE
1112
Now remove your Nest thermostat from the wall-plate to correct the wiring and check your equipment.
[after removing from wall-plate]
1113
Assembling technical information
1114
TECHNICAL INFO
NEST SUPPORT
nest.com/support
ERROR
#15 – no cooling
The backplate has failed in some way and the head unit knows it
1116
The Nest base has failed and must be replaced. Error #1
CONTINUE
[after removing from wall-plate]
1117
Assembling technical information
1118
TECHNICAL INFO
NEST SUPPORT
nest.com/support
ERROR
#1 – base

FIG. 11B

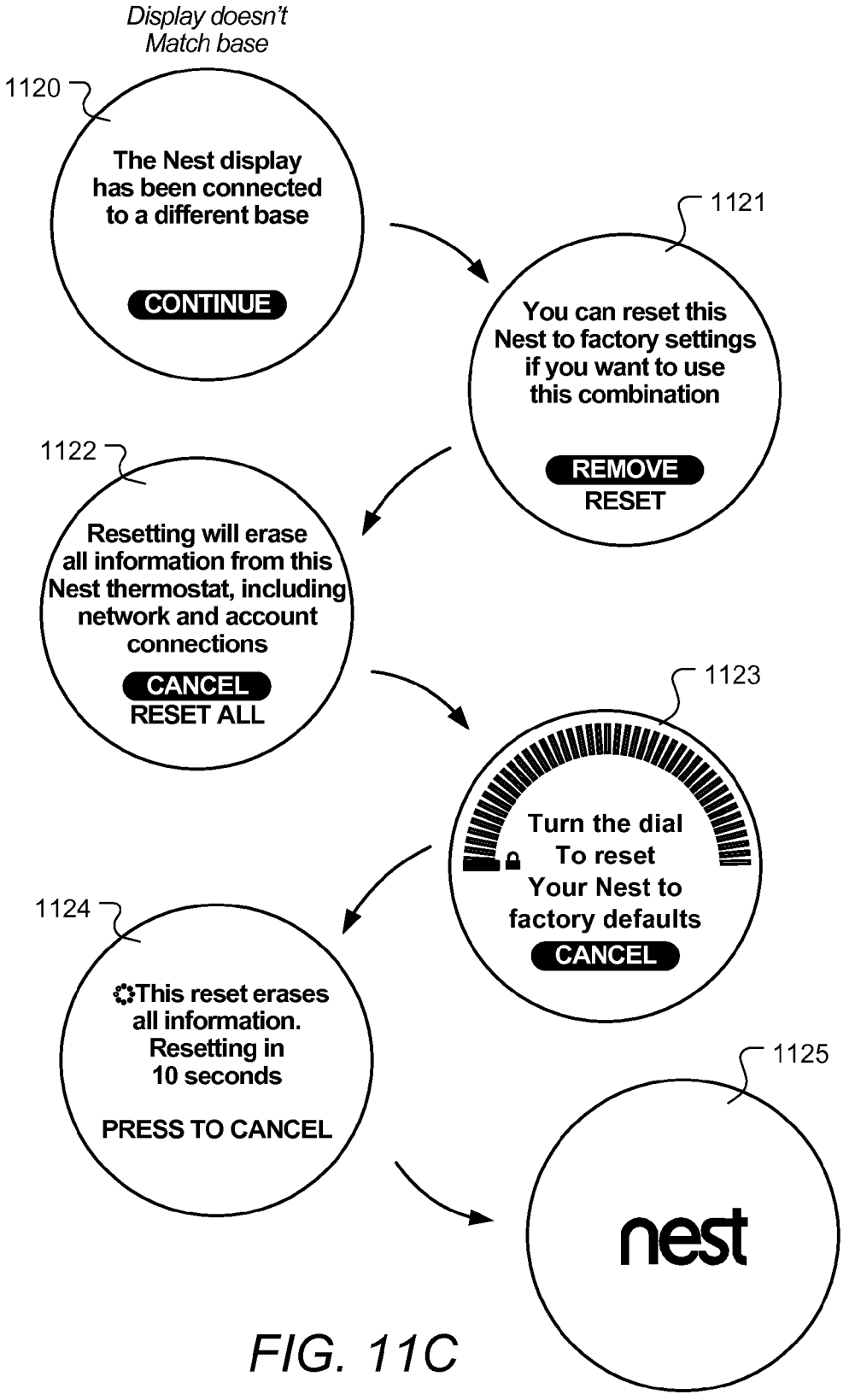
Display doesn't Match base
1120
The Nest display has been connected to a different base
CONTINUE
1121
You can reset this Nest to factory settings if you want to use this combination
REMOVE
RESET
1122
Resetting will erase all information from this Nest thermostat, including network and account connections
CANCEL
RESET ALL
1123
Turn the dial To reset Your Nest to factory defaults
CANCEL
1124
This reset erases all information. Resetting in 10 seconds
PRESS TO CANCEL
1125
nest

FIG. 11C

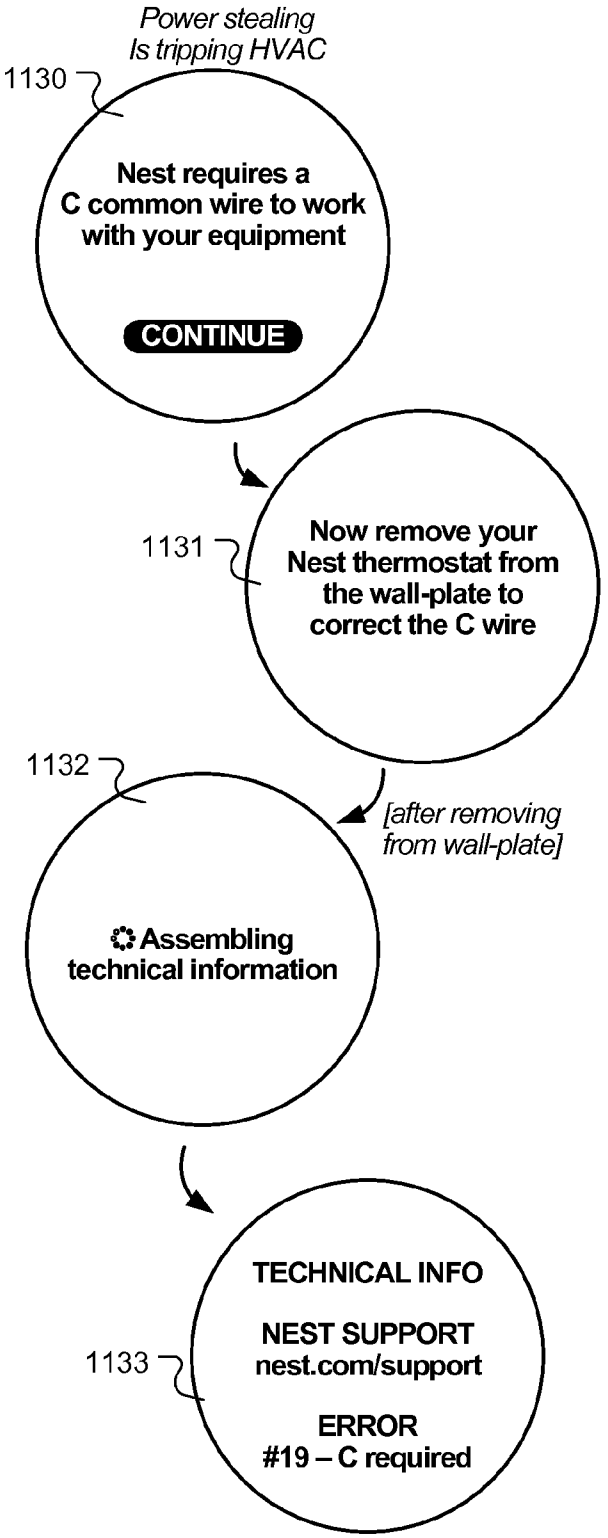
Power stealing
Is tripping HVAC
1130
Nest requires a
C common wire to work
with your equipment
CONTINUE
1131
Now remove your
Nest thermostat from
the wall-plate to
correct the C wire
1132
[after removing
from wall-plate]
Assembling
technical information
TECHNICAL INFO
NEST SUPPORT
nest.com/support
1133
ERROR
#19 – C required

FIG. 11D

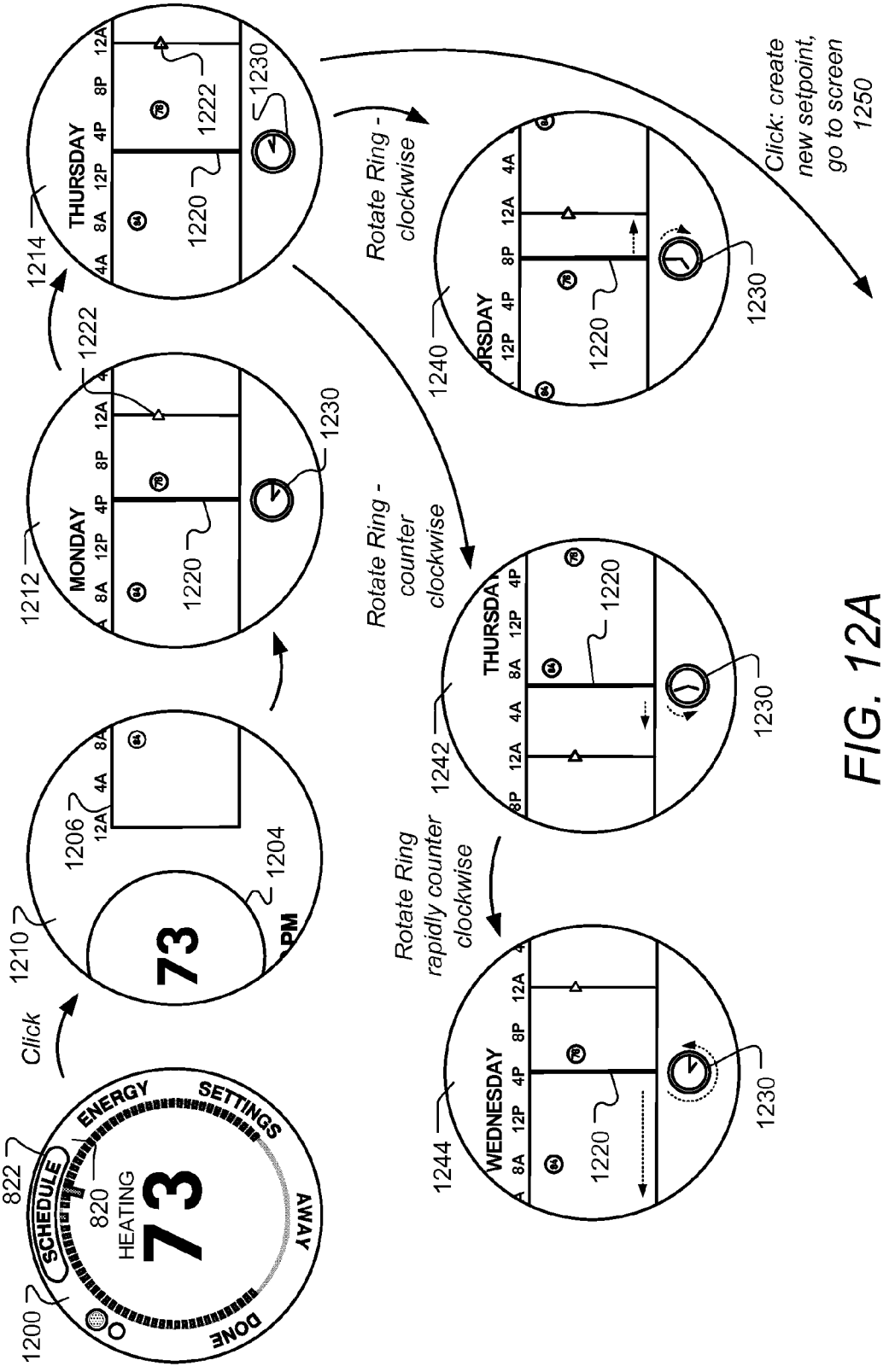
1200
822
SCHEDULE
ENERGY
SETTINGS
AWAY
DONE
820
HEATING
73
Click
1210
1206
1204
73
PM
1212
MONDAY
1220
1222
1230
1214
THURSDAY
Rotate Ring - clockwise
Rotate Ring - counter clockwise
Rotate Ring rapidly counter clockwise
1240
1242
1244
WEDNESDAY
Click: create new setpoint, go to screen 1250

FIG. 12A

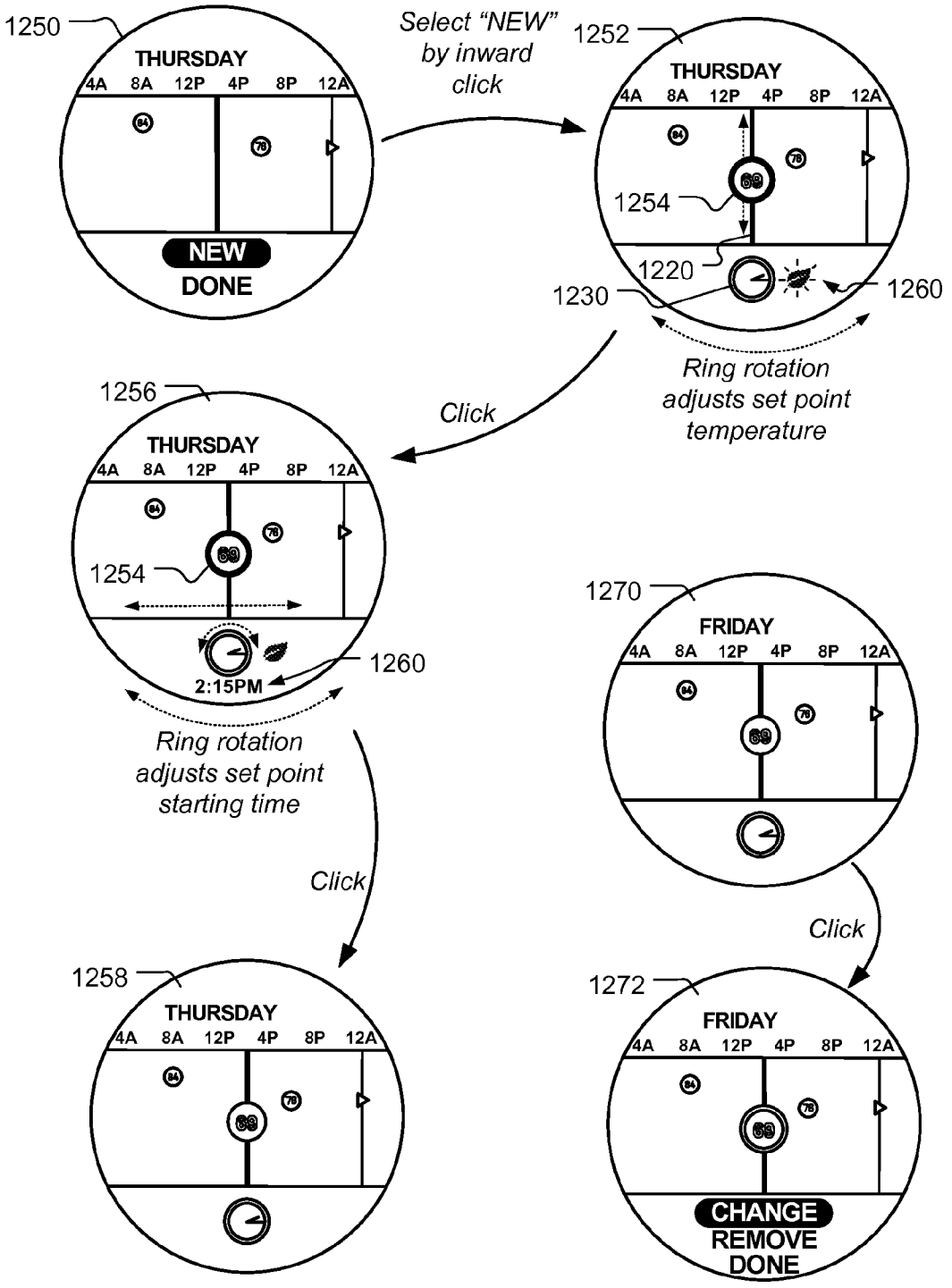
1250
THURSDAY
4A 8A 12P 4P 8P 12A
NEW
DONE
Select "NEW" by inward click
1252
THURSDAY
4A 8A 12P 4P 8P 12A
1254
1220
1230
1260
Ring rotation adjusts set point temperature
Click
1256
THURSDAY
4A 8A 12P 4P 8P 12A
1254
2:15PM
1260
Ring rotation adjusts set point starting time
Click
1270
FRIDAY
4A 8A 12P 4P 8P 12A
Click
1258
THURSDAY
4A 8A 12P 4P 8P 12A
1272
FRIDAY
4A 8A 12P 4P 8P 12A
CHANGE
REMOVE
DONE

FIG. 12B

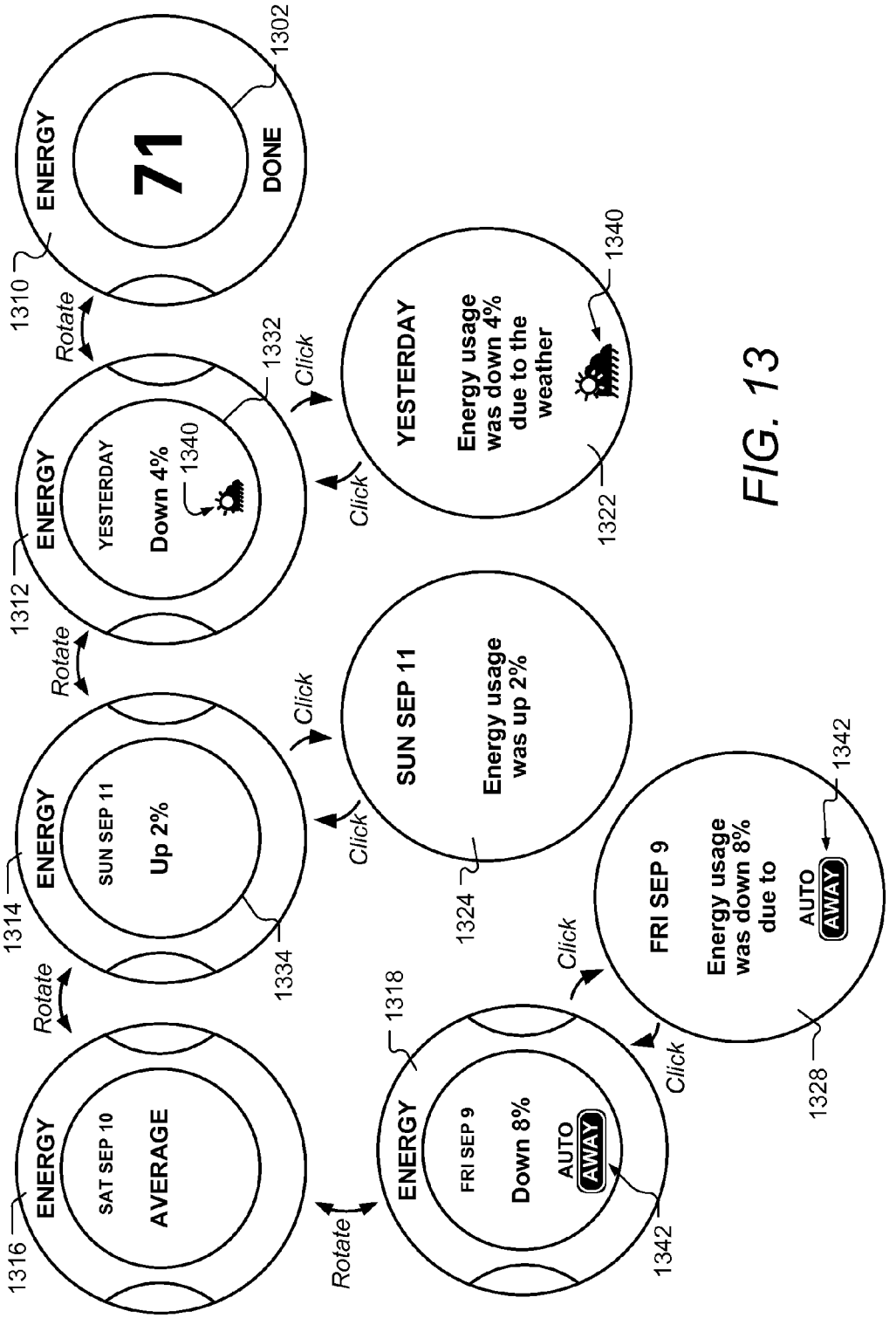
ENERGY
71
DONE
1302
1310
Rotate
ENERGY
YESTERDAY
Down 4%
1340
1332
1312
Click
YESTERDAY
Energy usage was down 4% due to the weather
1340
1322
Rotate
ENERGY
SUN SEP 11
Up 2%
1314
1334
Click
SUN SEP 11
Energy usage was up 2%
1324
Rotate
ENERGY
SAT SEP 10
AVERAGE
1316
Click
ENERGY
FRI SEP 9
Down 8%
AUTO
AWAY
1318
1342
Click
FRI SEP 9
Energy usage was down 8% due to
AUTO
AWAY
1342
1328
Rotate

FIG. 13

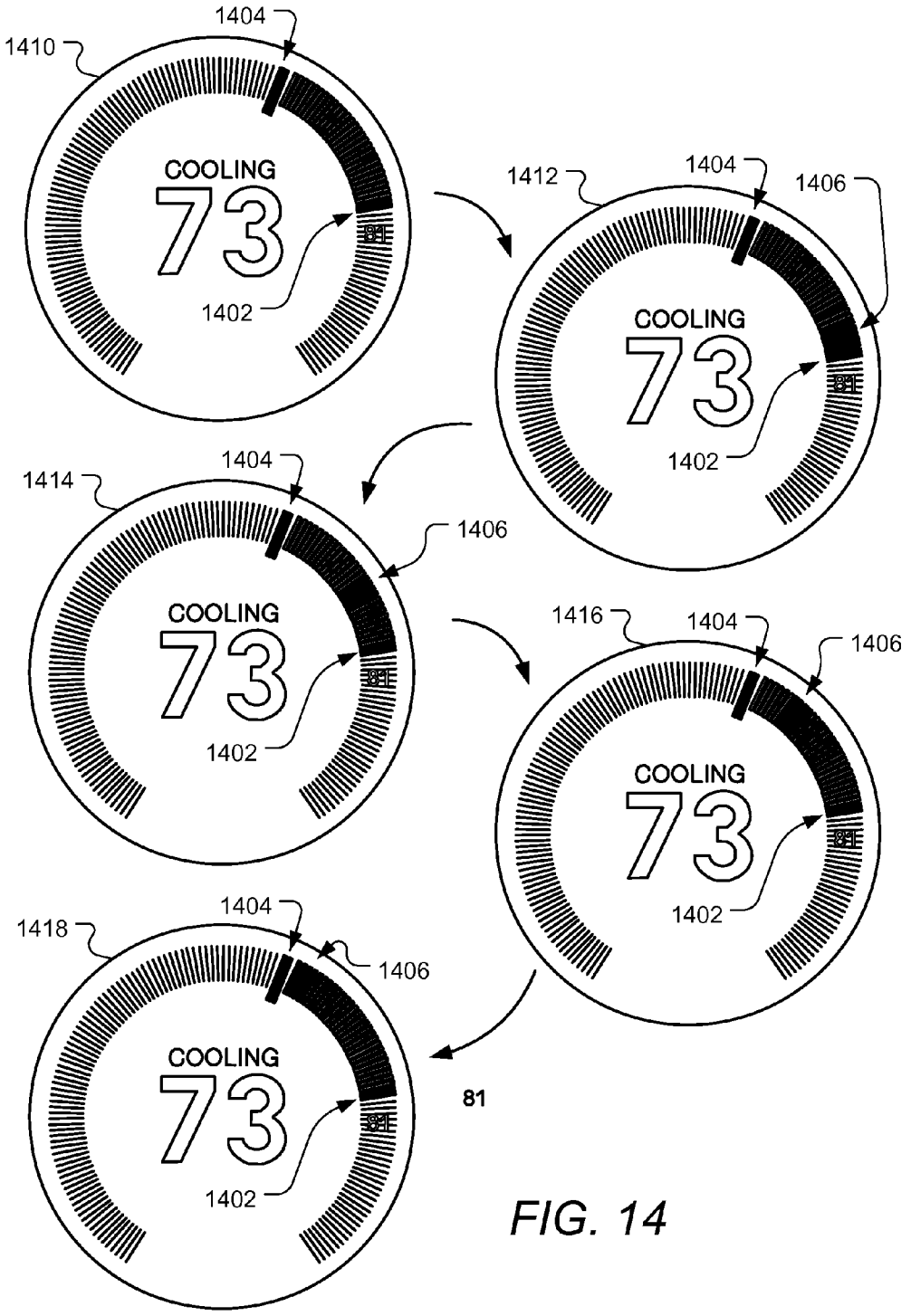
1404
1410
COOLING
73
1402
1412
1404
1406
COOLING
73
1402
1414
1404
1406
COOLING
73
1402
1416
1404
1406
COOLING
73
1402
1418
1404
1406
COOLING
73
1402
81

FIG. 14

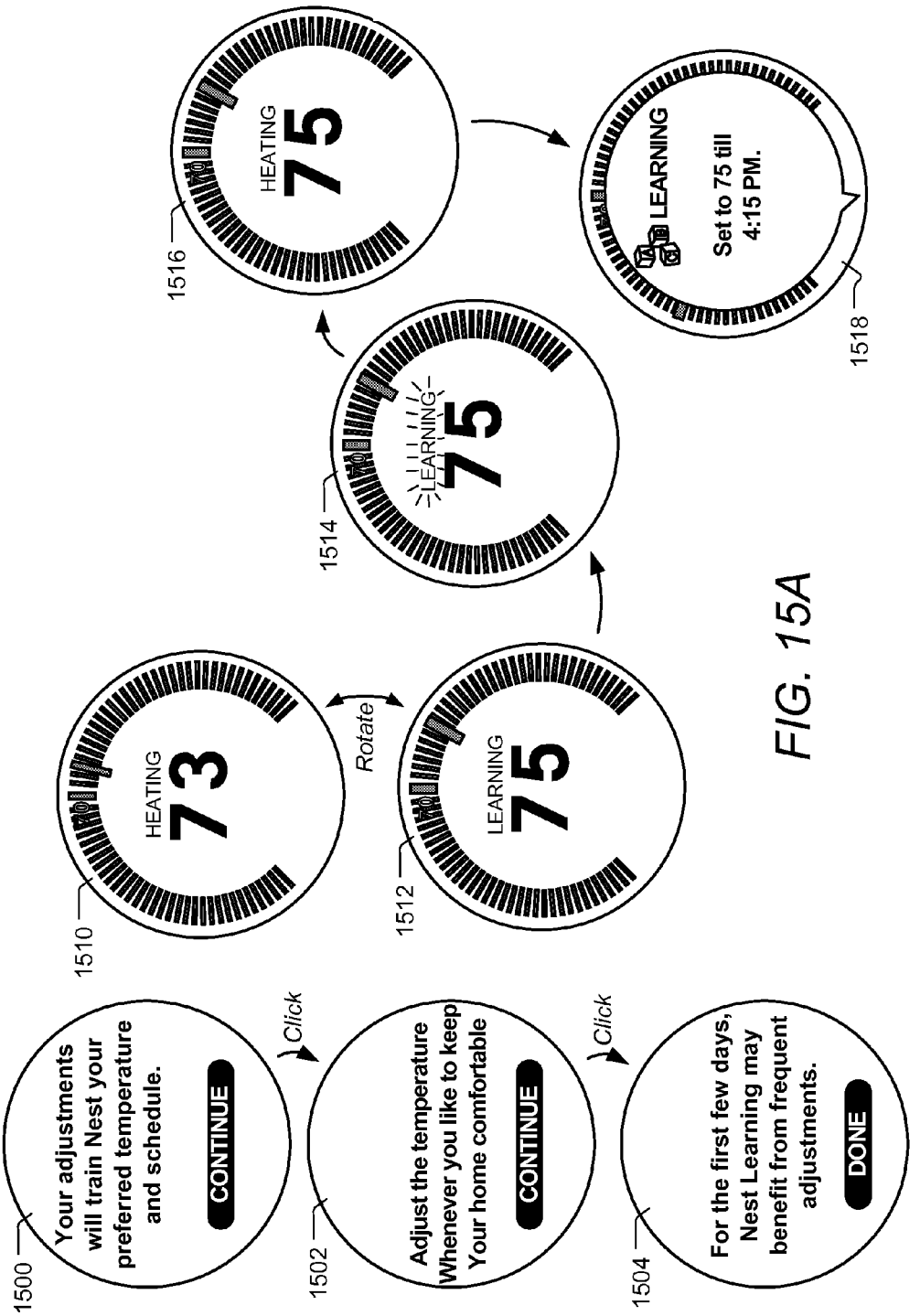
Your adjustments will train Nest your preferred temperature and schedule.
CONTINUE
1500
Click
Adjust the temperature Whenever you like to keep Your home comfortable
CONTINUE
1502
Click
For the first few days, Nest Learning may benefit from frequent adjustments.
DONE
1504
HEATING
73
1510
Rotate
LEARNING
75
1512
LEARNING
75
1514
HEATING
75
1516
LEARNING
Set to 75 till 4:15 PM.
1518

FIG. 15A

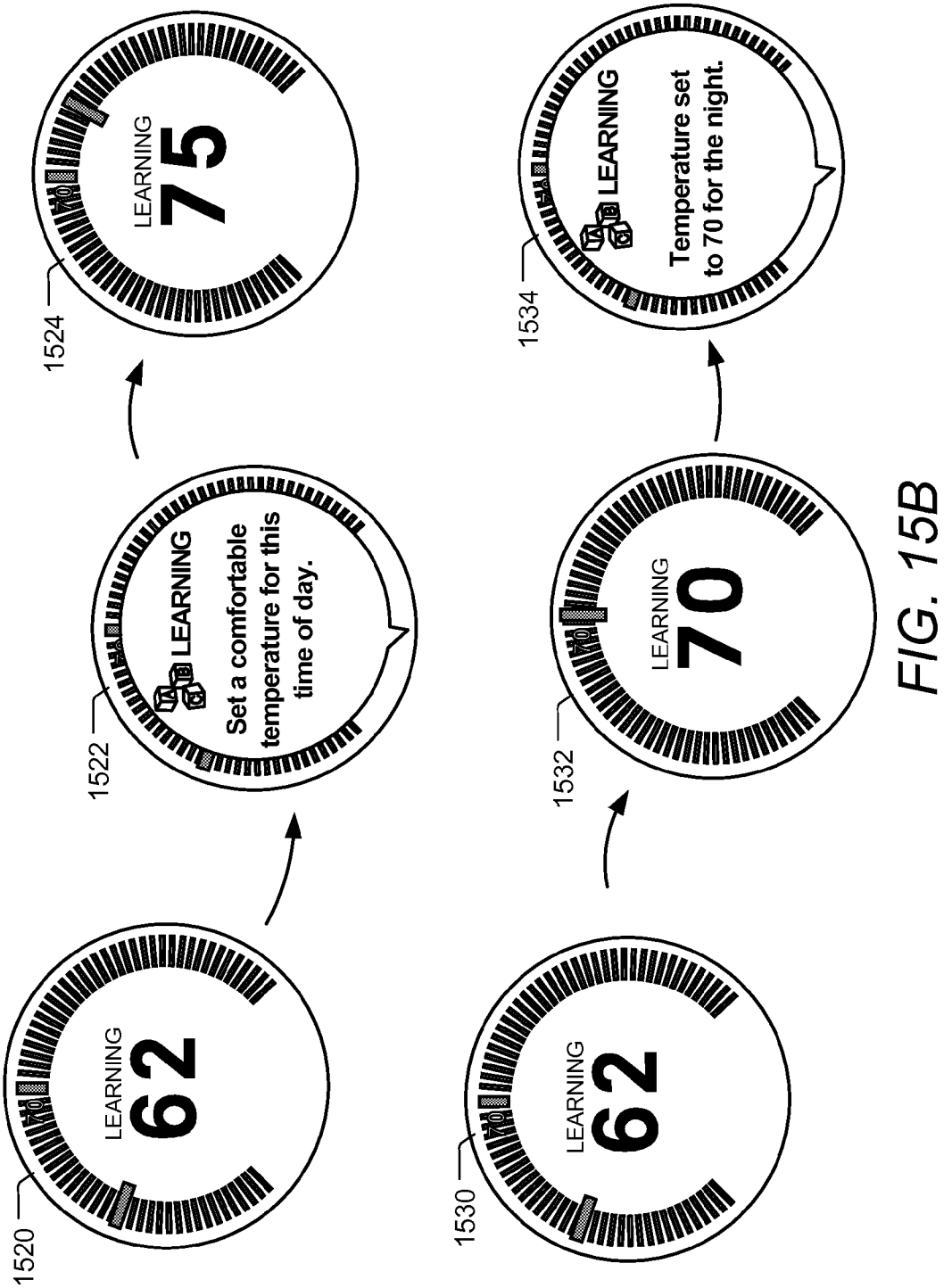
1520
LEARNING
62
1522
LEARNING
Set a comfortable temperature for this time of day.
1524
LEARNING
75
1530
LEARNING
62
1532
LEARNING
70
1534
LEARNING
Temperature set to 70 for the night.

FIG. 15B

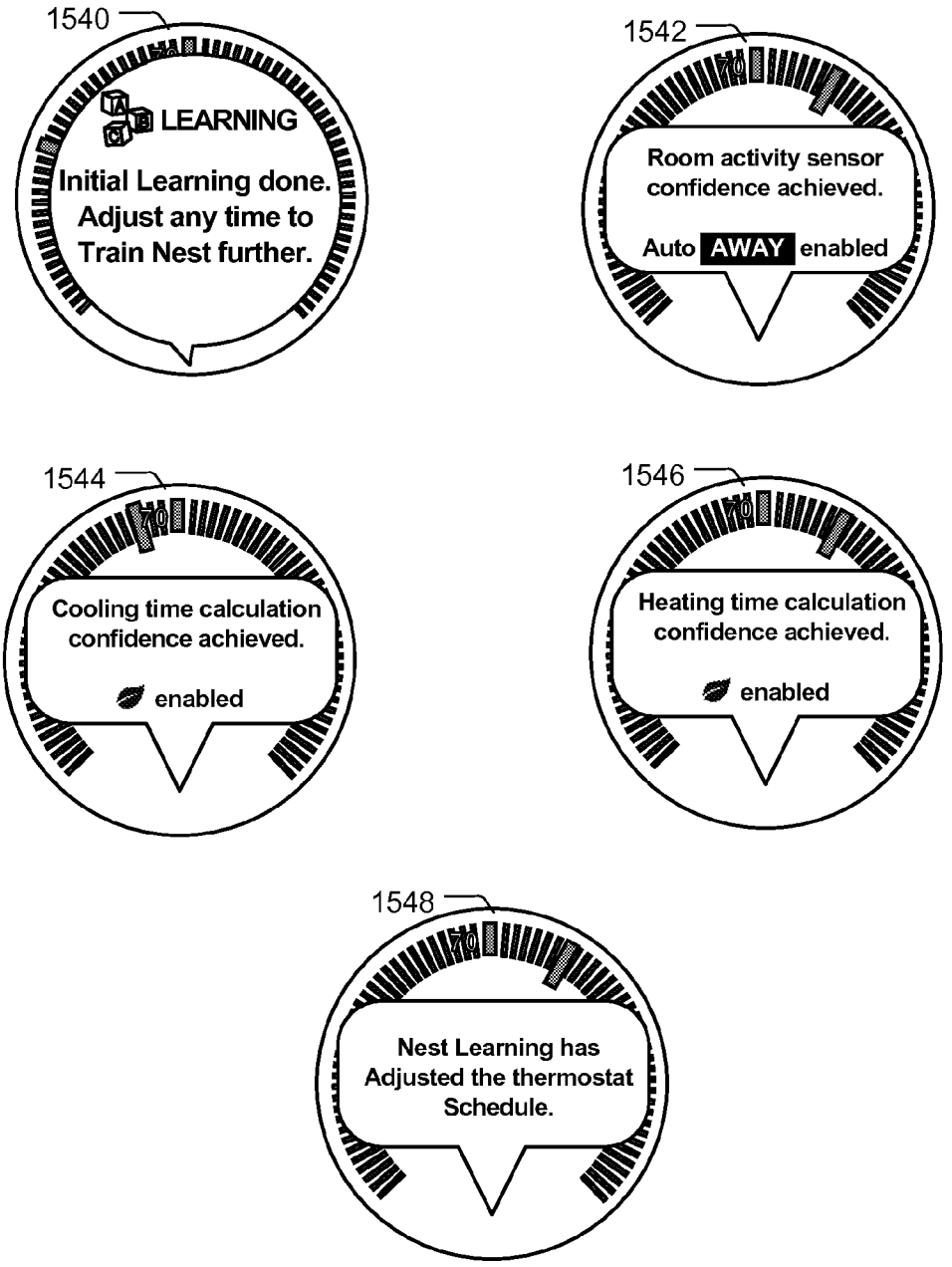
1540
LEARNING
Initial Learning done.
Adjust any time to
Train Nest further.
1542
Room activity sensor
confidence achieved.
Auto AWAY enabled
1544
Cooling time calculation
confidence achieved.
enabled
1546
Heating time calculation
confidence achieved.
enabled
1548
Nest Learning has
Adjusted the thermostat
Schedule.

FIG. 15C

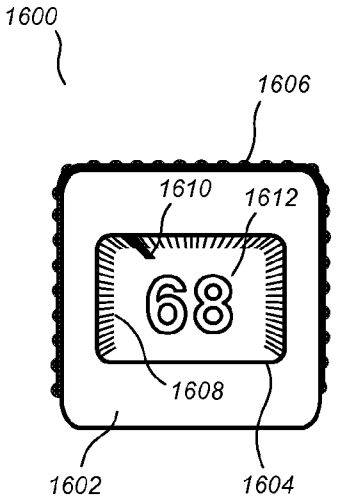

FIG. 16A

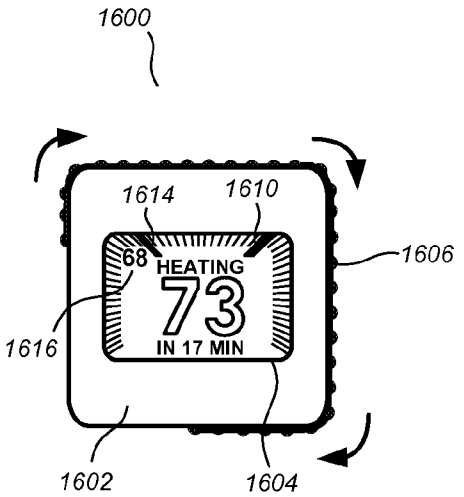

FIG. 16B

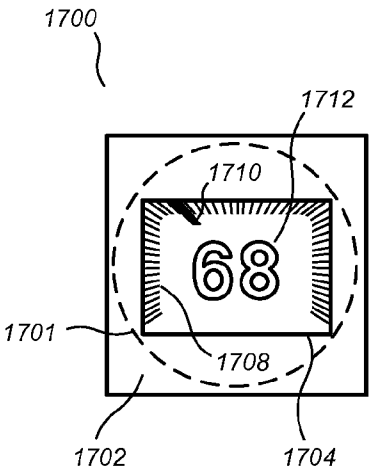

FIG. 17A

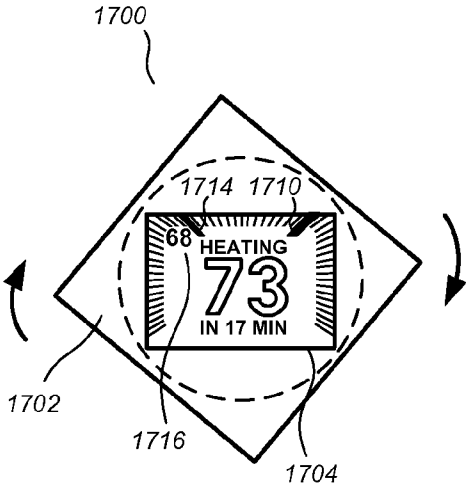

FIG. 17B

USER FRIENDLY INTERFACE FOR CONTROL UNIT

CROSS-REFERENCE TO RELATED APPLICATIONS

This patent is a continuation-in-part of U.S. Ser. No. 13/033,573, filed Feb. 23, 2011. This patent application also claims the benefit of U.S. Prov. Ser. No. 61/415,771 filed Nov. 19, 2010; and of U.S. Prov. Ser. No. 61/429,093 filed Dec. 31, 2010, each of which is incorporated by reference herein. The subject matter of this patent specification also relates to the subject matter of the following commonly assigned applications: U.S. Ser. No. 12/881,430 filed Sep. 14, 2010; U.S. Ser. No. 12/881,463 filed Sep. 14, 2010; U.S. Ser. No. 12/984,602 filed Jan. 4, 2011; U.S. Ser. No. 12/987,257 filed Jan. 10, 2011; U.S. Ser. No. 13/033,573 and US. Ser. No. 29/386,021, filed Feb. 23, 2011; U.S. Ser. No. 13/034,666, U.S. Ser. No. 13/034,674 and U.S. Ser. No. 13/034,678 filed Feb. 24, 2011; U.S. Ser. No. 13/038,206 and U.S. Ser. No. 13/038,191 filed Mar. 1, 2011; U.S. Ser. No. 29/399,609 filed Aug. 16, 2011; U.S. Ser. No. 29/399,614 filed Aug. 16, 2011; U.S. Ser. No. 29/399,617 filed Aug. 16, 2011; U.S. Ser. No. 29/399,618 filed Aug. 16, 2011; U.S. Ser. No. 29/399,621 filed Aug. 16, 2011; U.S. Ser. No. 29/399,623 filed Aug. 16, 2011; U.S. Ser. No. 29/399,625 filed Aug. 16, 2011; U.S. Ser. No. 29/399,627 filed Aug. 16, 2011; U.S. Ser. No. 29/399,630 filed Aug. 16, 2011; U.S. Ser. No. 29/399,632 filed Aug. 16, 2011; U.S. Ser. No. 29/399,633 filed Aug. 16, 2011; U.S. Ser. No. 29/399,636 filed Aug. 16, 2011; U.S. Ser. No. 29/399,637 filed Aug. 16, 2011; U.S. Ser. No. 13/199,108 filed Aug. 17, 2011; and U.S. Ser. No. 13/267,877 and U.S. Ser. No. 13/267,871 filed Oct. 6, 2011. Each of the above-referenced patent applications is incorporated by reference herein. The above-referenced patent applications are collectively referenced hereinbelow as "the commonly assigned incorporated applications."

FIELD

This patent specification relates to systems, methods, and related computer program products for the monitoring and control of energy-consuming systems or other resource-consuming systems. More particularly, this patent specification relates to user interfaces for control units that govern the operation of energy-consuming systems, household devices, or other resource-consuming systems, including user interfaces for thermostats that govern the operation of heating, ventilation, and air conditioning (HVAC) systems.

BACKGROUND

While substantial effort and attention continues toward the development of newer and more sustainable energy supplies, the conservation of energy by increased energy efficiency remains crucial to the world's energy future. According to an October 2010 report from the U.S. Department of Energy, heating and cooling account for 56% of the energy use in a typical U.S. home, making it the largest energy expense for most homes. Along with improvements in the physical plant associated with home heating and cooling (e.g., improved insulation, higher efficiency furnaces), substantial increases in energy efficiency can be achieved by better control and regulation of home heating and cooling equipment. By activating heating, ventilation, and air conditioning (HVAC) equipment for judiciously selected time intervals and carefully chosen operating levels, substantial energy can be saved while at the same time keeping the living space suitably comfortable for its occupants.

Historically, however, most known HVAC thermostatic control systems have tended to fall into one of two opposing categories, neither of which is believed be optimal in most practical home environments. In a first category are many simple, non-programmable home thermostats, each typically consisting of a single mechanical or electrical dial for setting a desired temperature and a single HEAT-FAN-OFF-AC switch. While being easy to use for even the most unsophisticated occupant, any energy-saving control activity, such as adjusting the nighttime temperature or turning off all heating/cooling just before departing the home, must be performed manually by the user. As such, substantial energy-saving opportunities are often missed for all but the most vigilant users. Moreover, more advanced energy-saving capabilities are not provided, such as the ability for the thermostat to be programmed for less energy-intensive temperature setpoints ("setback temperatures") during planned intervals of non-occupancy, and for more comfortable temperature setpoints during planned intervals of occupancy.

In a second category, on the other hand, are many programmable thermostats, which have become more prevalent in recent years in view of Energy Star (US) and TCO (Europe) standards, and which have progressed considerably in the number of different settings for an HVAC system that can be individually manipulated. Unfortunately, however, users are often intimidated by a dizzying array of switches and controls laid out in various configurations on the face of the thermostat or behind a panel door on the thermostat, and seldom adjust the manufacturer defaults to optimize their own energy usage. Thus, even though the installed programmable thermostats in a large number of homes are technologically capable of operating the HVAC equipment with energy-saving profiles, it is often the case that only the one-size-fits-all manufacturer default profiles are ever implemented in a large number of homes. Indeed, in an unfortunately large number of cases, a home user may permanently operate the unit in a "temporary" or "hold" mode, manually manipulating the displayed set temperature as if the unit were a simple, non-programmable thermostat.

Proposals have been made for so-called self-programming thermostats, including a proposal for establishing learned setpoints based on patterns of recent manual user setpoint entries as discussed in US20080191045A1, and including a proposal for automatic computation of a setback schedule based on sensed occupancy patterns in the home as discussed in G. Gao and K. Whitehouse, "The Self-Programming Thermostat: Optimizing Setback Schedules Based on Home Occupancy Patterns," Proceedings of the First ACM Workshop on Embedded Sensing Systems for Energy-Efficiency in Buildings, pp. 67-72, Association for Computing Machinery (November 2009). It has been found, however, that crucial and substantial issues arise when it comes to the practical integration of self-programming behaviors into mainstream residential and/or business use, issues that appear unaddressed and unresolved in such self-programming thermostat proposals. By way of example, just as there are many users who are intimidated by dizzying arrays of controls on user-programmable thermostats, there are also many users who would be equally uncomfortable with a thermostat that fails to give the user a sense of control and self-determination over their own comfort, or that otherwise fails to give confidence to the user that their wishes are indeed being properly accepted and carried out at the proper times. At a more general level, because of the fact that human beings must inevitably be

involved, there is a tension that arises between (i) the amount of energy-saving sophistication that can be offered by an HVAC control system, and (ii) the extent to which that energy-saving sophistication can be put to practical, everyday use in a large number of homes. Similar issues arise in the context of multi-unit apartment buildings, hotels, retail stores, office buildings, industrial buildings, and more generally any living space or work space having one or more HVAC systems. It has been found that the user interface of a thermostat, which so often seems to be an afterthought in known commercially available products, represents a crucial link in the successful integration of self-programming thermostats into widespread residential and business use, and that even subtle visual and tactile cues can make an large difference in whether those efforts are successful.

Thus, it would be desirable to provide a thermostat having an improved user interface that is simple, intuitive, elegant, and easy to use such that the typical user is able to access many of the energy-saving and comfort-maintaining features, while at the same time not being overwhelmed by the choices presented. It would be further desirable to provide a user interface for a self-programming or learning thermostat that provides a user setup and learning instantiation process that is relatively fast and easy to complete, while at the same time inspiring confidence in the user that their setpoint wishes will be properly respected. It would be still further desirable to provide a user interface for a self-programming or learning thermostat that provides convenient access to the results of the learning algorithms and methods for fast, intuitive alteration of scheduled setpoints including learned setpoints. It would be even further desirable to provide a user interface for a self-programming or learning thermostat that provides insightful feedback and encouragement regarding energy saving behaviors, performance, and/or results associated with the operation of the thermostat. Notably, although one or more of the embodiments described infra is particularly advantageous when incorporated with a self-programming or learning thermostat, it is to be appreciated that their incorporation into non-learning thermostats can be advantageous as well and is within the scope of the present teachings. Other issues arise as would be apparent to one skilled in the art upon reading the present disclosure.

SUMMARY

Provided according to one or more embodiments is a user interface for a programmable device, such as a programmable thermostat, that controls the operation of one or more energy-consuming systems, household devices, or other resource-consuming systems, such as a heating, ventilation, and air conditioning (HVAC) system. Further provided are systems, methods, computer program products, and related business methods associated with the user interface and programmable device. For some embodiments, the programmable device is configured to carry out a method for interacting with a user thereof, the method comprising displaying a plurality of background tick marks arcuately arranged within a range area on a rounded display that is centrally mounted on a rounded body of the programmable device. A setpoint tick mark is displayed on the rounded display within the range area such that the setpoint tick mark is more prominently visible to the user than the background tick marks, the setpoint tick mark representing a setpoint temperature. Numerical representations of the current temperature and the setpoint temperature are displayed on the rounded display, and input representing a desired change in the setpoint temperature is received from the user by user rotation of a rotatable ring surrounding the rounded display. The setpoint tick mark is moved in response to and in accordance with the received input such that the change in setpoint is visible to the user.

According to some embodiments, a background color having a red and/or orange shade is displayed when the device is calling for heating, and a background color having a bluish shade is displayed when the device is calling for cooling. For some embodiments, the displayed intensities of the colors correspond to an estimated amount of heating or cooling that will be used to reach the setpoint temperature.

According to some embodiments, there is provided a programmable device for controlling the operation of an HVAC system, the programmable device being configured to carry out a method for interacting with a user thereof, the method comprising displaying a menu including a plurality of user selectable options in an arcuate area on a rounded display that is centrally mounted on a rounded body of the programmable device, and receiving input from the user by user rotation of a rotatable ring surrounding the rounded display. Different user selectable options are highlighted in response to and in accordance with the received input. The arcuate area is preferably a circular outer area of the rounded display disposed along a periphery thereof, and the plurality of user selectable options are distributed about the circular area and are rotated about the display in response to the received input. For some embodiments, a highlighting window preferably remains in a fixed position relative to the device while the plurality of user selectable options are progressively rotated through the window such that only one of the user selectable options at a time is visible within the window. The currently highlighted option can be selected by the user by pressing the rotatable ring.

According to some embodiments, there is provided a programmable device for controlling the operation of an HVAC system, the programmable device being configured to carry out a method for interacting with a user thereof, the method comprising displaying a visible portion of a schedule plot on an electronic display that is centrally mounted on a body of the programmable device, the schedule plot having a time axis and including a plurality of programmed setpoints disposed at respective locations along the time axis. The method further comprises receiving input from the user by user rotation of a rotatable ring surrounding the rounded display, and progressively changing the visible portion of the schedule plot display in response to the received input. A stationary cursor is preferably overlaid on the displayed visible portion of the schedule plot, the cursor being representative of a time value by virtue of its location along the time axis of the schedule plot. The schedule plot is preferably moved in a direction of the time axis relative to the stationary cursor such that a progression of time intervals is represented on the display as a function of the received user input. Each programmed setpoint has an effective time that is characterized by its location along the time axis, and further has a temperature value that is characterized by its location along a temperature axis of the schedule plot. For some embodiments, the time axis is disposed along a horizontal direction while the temperature axis is disposed along a vertical direction. New programmed setpoints can be established, and existing programmed setpoints can be adjusted in terms of their effective time and/or temperature values, by intuitive sequences of user pressing and user rotation of the rotatable ring. To establish a new programmed setpoint, the user rotates the rotatable ring until the stationary cursor is coincident with the desired effective time, presses the rotatable ring to establish a new setpoint at that time axis location, rotates the rotatable ring to adjust the temperature value of the new setpoint, and then presses the rotatable ring again to establish the programmed setpoint

at that effective time and that temperature value. To adjust an existing programmed setpoint, the user rotates the rotatable ring until the stationary cursor is coincident with the effective time thereof, presses the rotatable ring to select that programmed setpoint, rotates the rotatable ring to adjust the time axis location, presses the rotatable ring to select the desired time location and allow adjustment of the temperature value, rotates the rotatable ring to adjust the temperature value, and again presses the rotatable ring to establish the new effective time and temperature value of the programmed setpoint.

According to some embodiments, a programmable device for controlling an HVAC system is provided. The device includes an electronic display positioned inside a circular outer ring that is user rotatable and user pressable, and a processor adapted and configured to drive the electronic display responsive to user presses and rotations of the outer ring. The processor is programmed to cause the electronic display to show recent energy usage performance information for a succession of recent historical time intervals. Energy performance information for respective time intervals can be displayed to the user in separate respective windows, the electronic display showing animated transitions between respective time intervals responsive to user rotations of the ring.

It will be appreciated that these systems and methods are novel, as are applications thereof and many of the components, systems, methods and algorithms employed and included therein. It should be appreciated that embodiments of the presently described inventive body of work can be implemented in numerous ways, including as processes, apparata, systems, devices, methods, computer readable media, computational algorithms, embedded or distributed software and/or as a combination thereof. Several illustrative embodiments are described below.

BRIEF DESCRIPTION OF THE DRAWINGS

The inventive body of work will be readily understood by referring to the following detailed description in conjunction with the accompanying drawings, in which:

FIG. **1** is a diagram of an enclosure in which environmental conditions are controlled, according to some embodiments;

FIG. **2** is a diagram of an HVAC system, according to some embodiments;

FIGS. **3**A-**3**B illustrate a thermostat having a user-friendly interface, according to some embodiments;

FIG. **3**C illustrates a cross-sectional view of a shell portion of a frame of the thermostat of FIGS. **3**A-**3**B;

FIG. **4** illustrates a thermostat having a head unit and a backplate (or wall dock) for ease of installation, configuration and upgrading, according to some embodiments;

FIGS. **5**A-F and **6**A-D illustrate display screens on a user-friendly graphical user interface for a programmable thermostat upon initial set up, according to some embodiments;

FIGS. **7**A-**7**K show aspects of a general layout of a graphical user interface for a thermostat, according to some embodiments;

FIGS. **8**A-C show example screens of a rotating main menu on a user-friendly a programmable thermostat, according to some preferred embodiments;

FIGS. **9**A-H and **10**A-I illustrate example user interface screens on a user-friendly a programmable thermostat for making various settings, according to some embodiments;

FIGS. **11**A-D show example screens for various error conditions on a user-friendly a programmable thermostat, according to some embodiments;

FIGS. **12**A and **12**B show certain aspects of user interface navigation trough a multi-day program schedule on a user-friendly programmable thermostat, according to some preferred embodiments;

FIG. **13** shows example screens relating to the display of energy usage information on a user-friendly a programmable thermostat, according to some embodiments;

FIG. **14** shows example screens for displaying an animated tick-sweep on a user-friendly a programmable thermostat, according to some embodiments;

FIGS. **15**A-C show example screens relating to learning on a user-friendly a programmable thermostat, according to some alternate embodiments;

FIGS. **16**A-B illustrate a thermostat having a user-friendly interface, according to some embodiments; and

FIGS. **17**A-B illustrate a thermostat having a user-friendly interface, according to some embodiments.

DETAILED DESCRIPTION

A detailed description of the inventive body of work is provided below. While several embodiments are described, it should be understood that the inventive body of work is not limited to any one embodiment, but instead encompasses numerous alternatives, modifications, and equivalents. In addition, while numerous specific details are set forth in the following description in order to provide a thorough understanding of the inventive body of work, some embodiments can be practiced without some or all of these details. Moreover, for the purpose of clarity, certain technical material that is known in the related art has not been described in detail in order to avoid unnecessarily obscuring the inventive body of work.

As used herein the term "HVAC" includes systems providing both heating and cooling, heating only, cooling only, as well as systems that provide other occupant comfort and/or conditioning functionality such as humidification, dehumidification and ventilation.

As used herein the terms power "harvesting," "sharing" and "stealing" when referring to HVAC thermostats all refer to the thermostat are designed to derive power from the power transformer through the equipment load without using a direct or common wire source directly from the transformer.

As used herein the term "residential" when referring to an HVAC system means a type of HVAC system that is suitable to heat, cool and/or otherwise condition the interior of a building that is primarily used as a single family dwelling. An example of a cooling system that would be considered residential would have a cooling capacity of less than about 5 tons of refrigeration (1 ton of refrigeration=12,000 Btu/h).

As used herein the term "light commercial" when referring to an HVAC system means a type of HVAC system that is suitable to heat, cool and/or otherwise condition the interior of a building that is primarily used for commercial purposes, but is of a size and construction that a residential HVAC system is considered suitable. An example of a cooling system that would be considered residential would have a cooling capacity of less than about 5 tons of refrigeration.

As used herein the term "thermostat" means a device or system for regulating parameters such as temperature and/or humidity within at least a part of an enclosure. The term "thermostat" may include a control unit for a heating and/or cooling system or a component part of a heater or air conditioner. As used herein the term "thermostat" can also refer generally to a versatile sensing and control unit (VSCU unit) that is configured and adapted to provide sophisticated, customized, energy-saving HVAC control functionality while at

the same time being visually appealing, non-intimidating, elegant to behold, and delightfully easy to use.

FIG. **1** is a diagram of an enclosure in which environmental conditions are controlled, according to some embodiments. Enclosure **100**, in this example is a single-family dwelling. According to other embodiments, the enclosure can be, for example, a duplex, an apartment within an apartment building, a light commercial structure such as an office or retail store, or a structure or enclosure that is a combination of the above. Thermostat **110** controls HVAC system **120** as will be described in further detail below. According to some embodiments, the HVAC system **120** is has a cooling capacity less than about 5 tons. According to some embodiments, a remote device **112** wirelessly communicates with the thermostat **110** and can be used to display information to a user and to receive user input from the remote location of the device **112**. Although many of the embodiments are described herein as being carried out by a thermostat such as thermostat **110**, according to some embodiments, the same or similar techniques are employed using a remote device such as device **112**.

FIG. **2** is a diagram of an HVAC system, according to some embodiments. HVAC system **120** provides heating, cooling, ventilation, and/or air handling for the enclosure, such as a single-family home **100** depicted in FIG. **1**. The system **120** depicts a forced air type heating system, although according to other embodiments, other types of systems could be used. In heating, heating coils or elements **242** within air handler **240** provide a source of heat using electricity or gas via line **236**. Cool air is drawn from the enclosure via return air duct **246** through filter **270**, using fan **238** and is heated heating coils or elements **242**. The heated air flows back into the enclosure at one or more locations via supply air duct system **252** and supply air grills such as grill **250**. In cooling, an outside compressor **230** passes gas such a Freon through a set of heat exchanger coils to cool the gas. The gas then goes to the cooling coils **234** in the air handlers **240** where it expands, cools and cools the air being circulated through the enclosure via fan **238**. According to some embodiments a humidifier **254** is also provided. Although not shown in FIG. **2**, according to some embodiments the HVAC system has other known functionality such as venting air to and from the outside, and one or more dampers to control airflow within the duct systems. The system is controlled by control electronics **212** whose operation is governed by a thermostat such as the thermostat **110**. Thermostat **110** controls the HVAC system **120** through a number of control circuits. Thermostat **110** also includes a processing system **260** such as a microprocessor that is adapted and programmed to controlling the HVAC system and to carry out the techniques described in detail herein.

FIGS. **3**A-B illustrate a thermostat having a user-friendly interface, according to some embodiments. Unlike many prior art thermostats, thermostat **300** preferably has a sleek, simple, uncluttered and elegant design that does not detract from home decoration, and indeed can serve as a visually pleasing centerpiece for the immediate location in which it is installed. Moreover, user interaction with thermostat **300** is facilitated and greatly enhanced over known conventional thermostats by the design of thermostat **300**. The thermostat **300** includes control circuitry and is electrically connected to an HVAC system, such as is shown with thermostat **110** in FIGS. **1** and **2**. Thermostat **300** is wall mounted, is circular in shape, and has an outer rotatable ring **312** for receiving user input. Thermostat **300** is circular in shape in that it appears as a generally disk-like circular object when mounted on the wall. Thermostat **300** has a large front face lying inside the outer ring **312**. According to some embodiments, thermostat **300** is approximately 80 mm in diameter. The outer rotatable ring **312** allows the user to make adjustments, such as selecting a new target temperature. For example, by rotating the outer ring **312** clockwise, the target temperature can be increased, and by rotating the outer ring **312** counter-clockwise, the target temperature can be decreased. The front face of the thermostat **300** comprises a clear cover **314** that according to some embodiments is polycarbonate, and a metallic portion **324** preferably having a number of slots formed therein as shown. According to some embodiments, the surface of cover **314** and metallic portion **324** form a common outward arc or spherical shape gently arcing outward, and this gentle arcing shape is continued by the outer ring **312**.

Although being formed from a single lens-like piece of material such as polycarbonate, the cover **314** has two different regions or portions including an outer portion **314***o* and a central portion **314***i*. According to some embodiments, the cover **314** is painted or smoked around the outer portion **314***o*, but leaves the central portion **314***i* visibly clear so as to facilitate viewing of an electronic display **316** disposed thereunderneath. According to some embodiments, the curved cover **314** acts as a lens that tends to magnify the information being displayed in electronic display **316** to users. According to some embodiments the central electronic display **316** is a dot-matrix layout (individually addressable) such that arbitrary shapes can be generated, rather than being a segmented layout. According to some embodiments, a combination of dot-matrix layout and segmented layout is employed. According to some embodiments, central display **316** is a backlit color liquid crystal display (LCD). An example of information displayed on the electronic display **316** is illustrated in FIG. **3**A, and includes central numerals **320** that are representative of a current setpoint temperature. According to some embodiments, metallic portion **324** has number of slot-like openings so as to facilitate the use of a passive infrared motion sensor **330** mounted therebeneath. The metallic portion **324** can alternatively be termed a metallic front grille portion. Further description of the metallic portion/front grille portion is provided in the commonly assigned U.S. Ser. No. 13/199,108, supra. The thermostat **300** is preferably constructed such that the electronic display **316** is at a fixed orientation and does not rotate with the outer ring **312**, so that the electronic display **316** remains easily read by the user. For some embodiments, the cover **314** and metallic portion **324** also remain at a fixed orientation and do not rotate with the outer ring **312**. According to one embodiment in which the diameter of the thermostat **300** is about 80 mm, the diameter of the electronic display **316** is about 45 mm. According to some embodiments an LED indicator **380** is positioned beneath portion **324** to act as a low-power-consuming indicator of certain status conditions. For, example the LED indicator **380** can be used to display blinking red when a rechargeable battery of the thermostat (see FIG. **4**A, infra) is very low and is being recharged. More generally, the LED indicator **380** can be used for communicating one or more status codes or error codes by virtue of red color, green color, various combinations of red and green, various different blinking rates, and so forth, which can be useful for troubleshooting purposes.

Motion sensing as well as other techniques can be use used in the detection and/or predict of occupancy, as is described further in the commonly assigned U.S. Ser. No. 12/881,430, supra. According to some embodiments, occupancy information is used in generating an effective and efficient scheduled program. Preferably, an active proximity sensor **370**A is provided to detect an approaching user by infrared light reflec-

tion, and an ambient light sensor **370**B is provided to sense visible light. The proximity sensor **370**A can be used to detect proximity in the range of about one meter so that the thermostat **300** can initiate "waking up" when the user is approaching the thermostat and prior to the user touching the thermostat. Such use of proximity sensing is useful for enhancing the user experience by being "ready" for interaction as soon as, or very soon after the user is ready to interact with the thermostat. Further, the wake-up-on-proximity functionality also allows for energy savings within the thermostat by "sleeping" when no user interaction is taking place our about to take place. The ambient light sensor **370**B can be used for a variety of intelligence-gathering purposes, such as for facilitating confirmation of occupancy when sharp rising or falling edges are detected (because it is likely that there are occupants who are turning the lights on and off), and such as for detecting long term (e.g., 24-hour) patterns of ambient light intensity for confirming and/or automatically establishing the time of day.

According to some embodiments, for the combined purposes of inspiring user confidence and further promoting visual and functional elegance, the thermostat **300** is controlled by only two types of user input, the first being a rotation of the outer ring **312** as shown in FIG. **3**A (referenced hereafter as a "rotate ring" or "ring rotation" input), and the second being an inward push on an outer cap **308** (see FIG. **3**B) until an audible and/or tactile "click" occurs (referenced hereafter as an "inward click" or simply "click" input). For the embodiment of FIGS. **3**A-**3**B, the outer cap **308** is an assembly that includes all of the outer ring **312**, cover **314**, electronic display **316**, and metallic portion **324**. When pressed inwardly by the user, the outer cap **308** travels inwardly by a small amount, such as 0.5 mm, against an interior metallic dome switch (not shown), and then springably travels back outwardly by that same amount when the inward pressure is released, providing a satisfying tactile "click" sensation to the user's hand, along with a corresponding gentle audible clicking sound. Thus, for the embodiment of FIGS. **3**A-**3**B, an inward click can be achieved by direct pressing on the outer ring **312** itself, or by indirect pressing of the outer ring by virtue of providing inward pressure on the cover **314**, metallic portion **314**, or by various combinations thereof. For other embodiments, the thermostat **300** can be mechanically configured such that only the outer ring **312** travels inwardly for the inward click input, while the cover **314** and metallic portion **324** remain motionless. It is to be appreciated that a variety of different selections and combinations of the particular mechanical elements that will travel inwardly to achieve the "inward click" input are within the scope of the present teachings, whether it be the outer ring **312** itself, some part of the cover **314**, or some combination thereof. However, it has been found particularly advantageous to provide the user with an ability to quickly go back and forth between registering "ring rotations" and "inward clicks" with a single hand and with minimal amount of time and effort involved, and so the ability to provide an inward click directly by pressing the outer ring **312** has been found particularly advantageous, since the user's fingers do not need to be lifted out of contact with the device, or slid along its surface, in order to go between ring rotations and inward clicks. Moreover, by virtue of the strategic placement of the electronic display **316** centrally inside the rotatable ring **312**, a further advantage is provided in that the user can naturally focus their attention on the electronic display throughout the input process, right in the middle of where their hand is performing its functions. The combination of intuitive outer ring rotation, especially as applied to (but not limited to) the changing of a thermostat's setpoint temperature, conveniently folded together with the satisfying physical sensation of inward clicking, together with accommodating natural focus on the electronic display in the central midst of their fingers' activity, adds significantly to an intuitive, seamless, and downright fun user experience. Further descriptions of advantageous mechanical user-interfaces and related designs, which are employed according to some embodiments, can be found in U.S. Ser. No. 13/033,573, supra, U.S. Ser. No. 29/386,021, supra, and U.S. Ser. No. 13/199,108, supra.

FIG. **3**C illustrates a cross-sectional view of a shell portion **309** of a frame of the thermostat of FIGS. **3**A-B, which has been found to provide a particularly pleasing and adaptable visual appearance of the overall thermostat **300** when viewed against a variety of different wall colors and wall textures in a variety of different home environments and home settings. While the thermostat itself will functionally adapt to the user's schedule as described herein and in one or more of the commonly assigned incorporated applications, supra, the outer shell portion **309** is specially configured to convey a "chameleon" quality or characteristic such that the overall device appears to naturally blend in, in a visual and decorative sense, with many of the most common wall colors and wall textures found in home and business environments, at least in part because it will appear to assume the surrounding colors and even textures when viewed from many different angles. The shell portion **309** has the shape of a frustum that is gently curved when viewed in cross-section, and comprises a sidewall **376** that is made of a clear solid material, such as polycarbonate plastic. The sidewall **376** is backpainted with a substantially flat silver- or nickel-colored paint, the paint being applied to an inside surface **378** of the sidewall **376** but not to an outside surface **377** thereof. The outside surface **377** is smooth and glossy but is not painted. The sidewall **376** can have a thickness T of about 1.5 mm, a diameter d**1** of about 78.8 mm at a first end that is nearer to the wall when mounted, and a diameter d**2** of about 81.2 mm at a second end that is farther from the wall when mounted, the diameter change taking place across an outward width dimension "h" of about 22.5 mm, the diameter change taking place in either a linear fashion or, more preferably, a slightly nonlinear fashion with increasing outward distance to form a slightly curved shape when viewed in profile, as shown in FIG. **3**C. The outer ring **312** of outer cap **308** is preferably constructed to match the diameter d**2** where disposed near the second end of the shell portion **309** across a modestly sized gap gltherefrom, and then to gently arc back inwardly to meet the cover **314** across a small gap g**2**. It is to be appreciated, of course, that FIG. **3**C only illustrates the outer shell portion **309** of the thermostat **300**, and that there are many electronic components internal thereto that are omitted from FIG. **3**C for clarity of presentation, such electronic components being described further hereinbelow and/or in other ones of the commonly assigned incorporated applications, such as U.S. Ser. No. 13/199,108, supra.

According to some embodiments, the thermostat **300** includes a processing system **360**, display driver **364** and a wireless communications system **366**. The processing system **360** is adapted to cause the display driver **364** and display area **316** to display information to the user, and to receiver user input via the rotatable ring **312**. The processing system **360**, according to some embodiments, is capable of carrying out the governance of the operation of thermostat **300** including the user interface features described herein. The processing system **360** is further programmed and configured to carry out other operations as described further hereinbelow and/or in other ones of the commonly assigned incorporated applica-

tions. For example, processing system **360** is further programmed and configured to maintain and update a thermodynamic model for the enclosure in which the HVAC system is installed, such as described in U.S. Ser. No. 12/881,463, supra. According to some embodiments, the wireless communications system **366** is used to communicate with devices such as personal computers and/or other thermostats or HVAC system components, which can be peer-to-peer communications, communications through one or more servers located on a private network, or and/or communications through a cloud-based service.

FIG. **4** illustrates a side view of the thermostat **300** including a head unit **410** and a backplate (or wall dock) **440** thereof for ease of installation, configuration and upgrading, according to some embodiments. As is described hereinabove, thermostat **300** is wall mounted and has circular in shape and has an outer rotatable ring **312** for receiving user input. Head unit **410** includes the outer cap **308** that includes the cover **314** and electronic display **316**. Head unit **410** of round thermostat **300** is slidably mountable onto back plate **440** and slidably detachable therefrom. According to some embodiments the connection of the head unit **410** to backplate **440** can be accomplished using magnets, bayonet, latches and catches, tabs or ribs with matching indentations, or simply friction on mating portions of the head unit **410** and backplate **440**. According to some embodiments, the head unit **410** includes a processing system **360**, display driver **364** and a wireless communications system **366**. Also shown is a rechargeable battery **420** that is recharged using recharging circuitry **422** that uses power from backplate that is either obtained via power harvesting (also referred to as power stealing and/or power sharing) from the HVAC system control circuit(s) or from a common wire, if available, as described in further detail in co-pending patent application U.S. Ser. Nos. 13/034,674, and 13/034,678, which are incorporated by reference herein. According to some embodiments, rechargeable battery **420** is a single cell lithium-ion, or a lithium-polymer battery.

Backplate **440** includes electronics **482** and a temperature/humidity sensor **484** in housing **460**, which are ventilated via vents **442**. Two or more temperature sensors (not shown) are also located in the head unit **410** and cooperate to acquire reliable and accurate room temperature data. Wire connectors **470** are provided to allow for connection to HVAC system wires. Connection terminal **480** provides electrical connections between the head unit **410** and backplate **440**. Backplate electronics **482** also includes power sharing circuitry for sensing and harvesting power available power from the HVAC system circuitry.

FIGS. **5**A-F and **6**A-D are display output flow diagrams illustrating a user-friendly graphical user interface for a programmable thermostat upon initial set up, according to some embodiments. The initial setup flow takes place, for example, when the thermostat **300** is removed from the box for the first time, or after a factory default reset instruction is made. The screens shown, according to some embodiments, are displayed on the thermostat **300** on round dot-matrix electronic display **316** having a rotatable ring **312**, such as shown and described supra with respect to FIGS. **3**A-**4**. In FIG. **5**A, the thermostat **300** with electronic display **316** shows a logo screen **510** upon initial startup. The logo screen **510** adds a spinner icon **513** in screen **512** to indicate to the user that the boot up process is progressing. According to some embodiments, information such as to inform the user of aspects of the thermostat **300** or aspects of the manufacturer is displayed to the user during the booting process. After booting, the screen **514** is displayed to inform the used that the initial setup process may take a few minutes. The user acknowledges the message by an inward click command, after which screen **516** is displayed. Screen **516** allows the user to select, via the rotatable ring, one of four setup steps. According to some embodiments, the user is not allowed to select the order of the set up steps, but rather the list of four steps is shown so that the user has an indication of current progress within the setup process. According to some preferred embodiments, the user can select either the next step in the progression, or any step that has already been completed (so as to allow re-doing of steps), but is not allowed to select a future step out of order (so as to prevent the user from inadvertently skipping any steps). According to one embodiment, the future steps that are not allowed yet are shown in a more transparent (or "greyed") color so as to indicate their current unavailability. In this case a click leads to screen **518**, which asks the user to connect to the internet to establish and/or confirm their unique cloud-based service account for features such as remote control, automatic updates and local weather information.

According to some embodiments, the transitions between some screens use a "coin flip" transition, and/or a translation or shifting of displayed elements as described in U.S. patent application Ser. No. 13/033,573, supra. The animated "coin flip" transition between progressions of thermostat display screens, which is also illustrated in the commonly assigned U.S. Ser. No. 29/399,625, supra, has been found to be advantageous in providing a pleasing and satisfying user experience, not only in terms of intrinsic visual delight, but also because it provides a unique balance between logical segregation (a sense that one is moving on to something new) and logical flow (a sense of connectedness and causation between the previous screen and the next screen). Although the type of transitions may not all be labeled in the figures herein, it is understood that different types of screen-to-screen transitions could be used so as to enhance the user interface experience for example by indicating to the user a transition to a different step or setting, or a return to a previous screen or menu.

In screen **518**, the user proceeds to the connection setup steps by selecting "CONNECT" with the rotatable ring followed by an inward click. Selecting "CONNECT" causes the thermostat **300** to scan for wireless networks and then to display screen **524** in FIG. **5**B. If the user selects "SKIP," then screen **520** is displayed, which informs the user that they can connect at any time from the settings menu. The user acknowledges this by clicking, which leads to screen **522**. In screen **522**, the first step "Internet Connection" is greyed out, which indicates that this step has been intentionally skipped.

In FIG. **5**B, screen **524** is shown after a scan is made for wireless networks (e.g. using Wi-Fi or ZigBee wireless communication). In the example shown in screen **524**, two wireless networks have been found and are displayed: "Network2" and "Network3." The electronic display **316** preferably also includes a lock icon **526** to show that the network uses password security, and also can show a wireless icon **528** to indicate the wireless connection to the network. According to some embodiments, wireless signal icon **528** can show a number of bars that indicates relative signal strength associated with that network. If the user selects one of the found networks that requires a password, screen **530** is displayed to obtain the password from the user. Screen **530** uses an alphanumeric input interface where the user selects and enters characters by rotating the ring and clicking. Further details of this type of data entry interface is described in the commonly assigned U.S. Ser. No. 13/033,573, supra. The user is reminded that a password is being entered by virtue of the lock icon **526**. After the password is entered, screen **532** is displayed while the thermostat tries to establish a connection

to the indicated Wi-Fi network. If the network connection is established and the internet is available, then the thermostat attempts to connect to the manufacturer's server. A successful connection to the server is shown in screen **534**. After a pause (or a click to acknowledge) screen **536** is displayed that indicates that the internet connection setup step has been successfully completed. According to some embodiments, a checkmark icon **537** is used to indicate successful completion of the step.

If no connection to the selected local network could be established, screen **538** is displayed notifying the user of such and asking if a network testing procedure should be carried out. If the user selects "TEST," then screen **540**, with a spinner icon **541**, is displayed while a network test is carried out. If the test discovers an error, a screen such as screen **542** is displayed to indicate the nature of the errors. According to some embodiments, the user is directed to further resources online for more detailed support.

If the local network connection was successful, but no connection to the manufacturer's server could be established then, in FIG. **5**C, screen **544**, the user is notified of the status and acknowledges by clicking "CONTINUE." In screen **546**, the user is asked if they wish to try a different network. If the user selects "NETWORK," then the thermostat scans for available networks and then moves to screen **524**. If the user selects "SKIP," then screen **522** is displayed.

Under some circumstances, for example following a network test (screen **540**) the system determines that a software and/or firmware update is needed. In such cases, screen **548** is displayed while the update process is carried out. Since some processes, such as downloading and installing updates, can take a relatively long time, a notice combined with a spinner **549** having a percent indicator can be shown to keep the user informed of the progress. Following the update, the system usually needs to be rebooted. Screen **550** informs the user of this.

According to some embodiments, in cases where more than one thermostat is located in the same dwelling or business location, the units can be associated with one another as both being paired to the user's account on a cloud-based management server. When a successful network and server connection is established (screen **534**), and if the server notes that there is already an online account associated with the current location by comparison of a network address of the thermostat **300** with that of other currently registered thermostats, then screen **552** is displayed, asking the user if they want to add the current thermostat to the existing account. If the user selects "ADD," the thermostat is added to the existing account as shown in screens **554** and **556**. After adding the current thermostat to the online account. If there is more than one thermostat on the account a procedure is offered to copy settings, beginning with screen **558**. In FIG. **5**D, screen **558** notifies the user that another thermostat, in this case named "Living Room," is also associated with the user's account, and asks the user if the settings should be copies. If the user selects "COPY SETTINGS" then the screen **560** is displayed with a spinner **561** while settings are copied to the new thermostat. According to some embodiments, one or more of the following settings are copied: account pairing, learning preferences (e.g. "learning on" or "learning off"), heating or cooling mode (if feasible), location, setup interview answers, current schedule and off-season schedule (if any).

Advantageous functionalities can be provided by two different instances of the thermostat unit **300** located in a common enclosure, such as a family home, that are associated with a same user account in the cloud-based management server, such as the account "tomsmith3@mailhost.com" in FIGS. **5**C-**5**D. For purposes of the present description it can be presumed that each thermostat is a "primary" thermostat characterized in that it is connected to an HVAC system and is responsible for controlling that HVAC system, which can be distinguished from an "auxiliary" thermostat having many of the same sensing and processing capabilities of the thermostat **300** except that an "auxiliary" thermostat does not connect to an HVAC system, but rather influences the operation of one or more HVAC systems by virtue of its direct or indirect communication with one or more primary thermostats. However, the scope of the present disclosure is not so limited, and thus in other embodiments there can be cooperation among various combinations of primary and/or auxiliary thermostats.

A particular enclosure, such as a family home, can use two primary thermostats **300** where there are two different HVAC systems to control, such as a downstairs HVAC system located on a downstairs floor and an upstairs HVAC system located on an upstairs floor. Where the thermostats have become logically associated with a same user account at the cloud-based management server, such as by operation of the screens **552**, **554**, **556**, the two thermostats advantageously cooperate with one another in providing optimal HVAC control of the enclosure as a whole. Such cooperation between the two thermostats can be direct peer-to-peer cooperation, or can be supervised cooperation in which the central cloud-based management server supervises them as one or more of a master, referee, mediator, arbitrator, and/or messenger on behalf of the two thermostats. In one example, an enhanced auto-away capability is provided, wherein an "away" mode of operation is invoked only if both of the thermostats have sensed a lack of activity for a requisite period of time. For one embodiment, each thermostat will send an away-state "vote" to the management server if it has detected inactivity for the requisite period, but will not go into an "away" state until it receives permission to do so from the management server. In the meantime, each thermostat will send a revocation of its away-state vote if it detects occupancy activity in the enclosure. The central management server will send away-state permission to both thermostats only if there are current away-state votes from each of them. Once in the collective away-state, if either thermostat senses occupancy activity, that thermostat will send a revocation to the cloud-based management server, which in turn will send away-state permission revocation (or an "arrival" command) to both of the thermostats. Many other types of cooperation among the commonly paired thermostats (i.e., thermostats associated with the same account at the management server) can be provided without departing from the scope of the present teachings.

Where there is more than one thermostat for a particular enclosure and those thermostats are associated with the same account on the cloud-based management server, one preferred method by which that group of thermostats can cooperate to provide enhanced auto-away functionality is as follows. Each thermostat maintains a group state information object that includes (i) a local auto-away-ready (AAR) flag that reflects whether that individual thermostat considers itself to be auto-away ready, and (ii) one or more peer auto-away-ready (AAR) flags that reflect whether each other thermostat in the group considers itself to be auto-away ready. The local AAR flag for each thermostat appears as a peer AAR flag in the group state information object of each other thermostat in the group. Each thermostat is permitted to change its own local AAR flag, but is only permitted to read its peer AAR flags. It is a collective function of the central cloud-based management server and the thermostats to communicate often enough such that the group state information

object in each thermostat is maintained with fresh information, and in particular that the peer AAR flags are kept fresh. This can be achieved, for example, by programming each thermostat to immediately communicate any change in its local AAR flag to the management server, at which time the management server can communicate that change immediately with each other thermostat in the group to update the corresponding peer AAR flag. Other methods of direct peer-to-peer communication among the thermostats can also be used without departing from the scope of the present teachings.

According to a preferred embodiment, the thermostats operate in a consensus mode such that each thermostat will only enter into an actual "away" state if all of the AAR flags for the group are set to "yes" or "ready". Therefore, at any particular point in time, either all of the thermostats in the group will be in an "away" state, or none of them will be in the "away" state. In turn, each thermostat is configured and programmed to set its AAR flag to "yes" if either or both of two sets of criteria are met. The first set of criteria is met when all of the following are true: (i) there has been a period of sensed inactivity for a requisite inactivity interval according to that thermostat's sensors such as its passive infrared (PIR) motion sensors, active infrared proximity sensors (PROX), and other occupancy sensors with which it may be equipped; (ii) the thermostat is "auto-away confident" in that it has previously qualified itself as being capable of sensing statistically meaningful occupant activity at a statistically sufficient number of meaningful times, and (iii) other basic "reasonableness criteria" for going into an auto-away mode are met, such as (a) the auto-away function was not previously disabled by the user, (b) the time is between 8 AM and 8 PM if the enclosure is not a business, (c) the thermostat is not in OFF mode, (d) the "away" state temperature is more energy-efficient than the current setpoint temperature, and (e) the user is not interacting with the thermostat remotely through the cloud-based management server. The second set of criteria is met when all of the following are true: (i) there has been a period of sensed inactivity for a requisite inactivity interval according to that thermostat's sensors, (ii) the AAR flag of at least one other thermostat in the group is "yes", and (iii) the above-described "reasonableness" criteria are all met. Advantageously, by special virtue of the second set of alternative criteria by which an individual thermostat can set its AAR flag to "yes", it can be the case that all of the thermostats in the group can contribute the benefits of their occupancy sensor data to the group auto-away determination, even where one or more of them are not "auto-away confident," as long as there is at least one member that is "auto-away confident." This method has been found to increase both the reliability and scalability of the energy-saving auto-away feature, with reliability being enhanced by virtue of multiple sensor locations around the enclosure, and with scalability being enhanced in that the "misplacement" of one thermostat (for example, installed at an awkward location behind a barrier that limits PIR sensitivity) causing that thermostat to be "away non-confident" will not jeopardize the effectiveness or applicability of the group consensus as a whole.

It is to be appreciated that the above-described method is readily extended to the case where there are multiple primary thermostats and/or multiple auxiliary thermostats. It is to be further appreciated that, as the term primary thermostat is used herein, it is not required that there be a one-to-one correspondence between primary thermostats and distinct HVAC systems in the enclosure. For example, there are many installations in which plural "zones" in the enclosure may be served by a single HVAC system by virtue of controllable dampers that can stop and/or redirect airflow to and among the different zones from the HVAC system. In such cases, there can be a primary thermostat for each zone, each of the primary thermostats being wired to the HVAC system as well as to the appropriate dampers to regulate the climate of its respective zone.

Referring now again to FIG. **5**D, in screen **562** a name is entered for the thermostat, assuming the thermostat is being installed in a dwelling rather than in a business. The list of choices **563** is larger than the screen allows, so according to some embodiments the list **563** scrolls up and down responsive to user ring rotation so the user can view all the available choices. For purposes of clarity of description, it is to be appreciated that when a listing of menu choices is illustrated in the drawings of the present disclosure as going beyond the spatial limits of a screen, such as shown with listing **563** of screen **562**, those menu choices will automatically scroll up and down as necessary to be viewable by the user as they rotate the rotatable ring **312**. The available choices of names in this case are shown, including an option to enter a custom name (by selecting "TYPE NAME"). The first entry "Nest 2" is a generic thermostat name, and assumes there is already a thermostat on the account named "Nest 1." If there already is a "Nest 2" thermostat then the name "Nest 3" will be offered, and so on. If the user selects "TYPE NAME," then a character entry user interface **565** is used to enter a name. Screen **564** shows a thermostat naming screen analogous to screen **562** except that is represents a case in which the thermostat **300** is being installed in a business rather than a dwelling. Screen **566** is displayed when thermostat learning (or self-programing) features are turned "on." In this case the user is asked if the current schedule from the other thermostat should be copied. Screens **568**, **570** and **572** show what is displayed after completion of the Internet connection, server connection and pairing procedures are completed. Screen **568** is used in the case there an Internet connection is established, but no pairing is made with a user account on the server. Screen **570** is used in the case where both an Internet connection and pairing the user's account on the server is established. Finally, screen **572** is used in the case where no internet connection was successfully established. In all cases the next setup topic is "Heating and Cooling."

FIG. **5**E shows example screens, according to some embodiments, for a thermostat that has the capability to detect wiring status and errors, such as described in the commonly assigned U.S. Ser. No. 13/034,666, supra, by detecting both the physical presence of a wire connected to the terminal, as well as using an analog-to-digital converter (ADC) to sense the presence of appropriate electrical signals on the connected wire. According to some embodiments, the combination of physical wire presence detection and ADC appropriate signal detection can be used to detect wiring conditions such as errors, for example by detecting whether the signal on an inserted wire is fully energized, or half-rectified. Screen **574** is an example when no wiring warnings or errors are detected. According to some preferred embodiments, the connectors that have wires attached are shown in a different color and additionally small wire stubs, such as stub **575**, are shown indicating to the user that a wire is connected to that connector terminal. According to some preferred embodiments, the wire stubs, such as stub **575**, are shown in a color that corresponds to the most common wire color that is found in the expected installation environment. For example, in the case of screen **574**, the wire stub for connector R_H is red, the wire stub for connector Y_1 is yellow, the wire stub for connector G is green and so on. Screen **578** is an example of a wiring warning indication screen. In general a wiring warning is used when

potential wiring problem is detected, but HVAC functionality is not blocked. In this case, a cooling wire Y1 is detected but no cooling system appears to be present, as notified to the user in screen **579**. Other examples of wiring warnings, according to some embodiments, include: Rh pin detected (i.e., the insertion of a wire into the Rh terminal has been detected) but that Rh wire is not live; Rc pin detected but Rc wire not live; W1 pin detected but W1 wire not live; AUX pin detected but AUX wire not live; G pin detected but G wire not live; and OB pin detected but OB wire not live. Screen **580** is an example of a wiring error indication screen. In general, wiring errors are detected problems that are serious enough such that HVAC functionality is blocked. In this case the wiring error shown in screen **580** is the absence of detected power wires (i.e., neither Rc nor Rh wires are detected), as shown in screen **582**. In screen **584**, the user is asked to confirm that the heating or cooling system is connected properly, after which the system shuts down as indicated by the blank (or black) screen **585**. Other examples of wiring errors, according to some embodiments, include: neither a Y1 nor a W1 pin has been detected; C pin detected but that C wire is not live; Y1 pin has been detected but that Y1 wire is not live; and a C wire is required (i.e., an automated power stealing test has been performed in which it has been found that the power stealing circuitry in thermostat **300** will undesirably cause one or more HVAC call relays to trip, and so power stealing cannot be used in this installation, and therefore it is required that a C wire be provided to the thermostat **300**).

FIG. **5**F show user interface screens relating to location and time/date, according to some embodiments. Screen **586** shows an example of the electronic display **316** when the first two steps of the setup process are completed. Upon user selection of "Your location" screen **588** is displayed to notify the user that a few questions should be answered to create a starting schedule. In screen **590**, the user's location country is identified. Note that the list of countries in this example is only USA and Canada, but in general other or larger lists of countries could be used. Screen **592** shows an example of a fixed length character entry field, in this case, entry of a numerical five-digit United States ZIP code. The use rotates the rotatable ring **312** (see FIG. **3**A, supra) to change the value of the highlighted character, followed by a click to select that value. Screen **594** shows an example after all five digits have been entered. Screen **596** shows an example of a screen that is used if the thermostat is not connected to the Internet, for entering date and time information. According to some embodiments, the time and date entry are only displayed when the clock has been reset to the firmware default values.

FIG. **6**A shows example user interface screens of setup interview questions for the user to answer, according to some embodiments. The screens shown, according to some embodiments, are displayed on a thermostat **300** on round dot-matrix electronic display **316** having a rotating ring **312** such as shown and described in FIGS. **3**A-**4**. Screen **600** shows the setup steps screen that is displayed once the first three steps have been completed. Note that if one of the steps has not been successful, a "–" symbol can be marked instead of a check mark. For example, if the internet connection was not made or skipped, a minus symbol "–" precedes the internet step. If "Your Home" is selected, screen **602** asks the user if the thermostat is being installed in a home or business. If "HOME" is selected, a number of questions **604** can be asked to aid in establishing a basic schedule for the user. Following the interview questions, in screen **608**, the user is asked to give the thermostat a name. Notably, the step **608** is only carried out if there was not already a name requested previously (see FIG. **5**D, step **562**), that is, if the thermostat currently being setup is not the first such thermostat being associated with the user's cloud-based service account. A list of common names **607** is displayed for the user to choose by scrolling via the rotatable ring. The user can also select "TYPE NAME" to enter a custom name via character input interface **609**. If the indicates that the thermostat is being installed in a business, then a set of interview questions **606** can be presented to aid in establishing a basic schedule. Following questions **606**, the user is asked to give the thermostat a name in an analogous fashion as described in the case of a home installation.

FIG. **6**B shows further interview questions associated with an initial setup procedure, according to some embodiments. Following the thermostat naming, in screen **610**, the user is asked if electric heat is used in the home or business. According to some embodiments, the heating questions shown are only asked if a wire is connected to the "W1" and/or "W2" terminals. In screen **612**, the user is asked if forced-air heating is used. Screen **614** informs the user that a testing procedure is being carried out in the case where a heat-pump heating system is used. For example, the test could be to determine proper polarity for the heat pump control system by activating the system and detecting resulting temperature changes, as described in the commonly assigned U.S. Ser. No. 13/038,191, supra. Screen **616** shows an example displayed to the user to inform the user that a relatively long procedure is being carried out. According to some embodiments, the heat pump test is not carried out if the user is able to correctly answer questions relating to the polarity of the heat pump system. Screen **620** show an example of where all the setup steps are successfully completed. If the user selects "FINISH" a summary screen **622** of the installation is displayed, indicating the installed HVAC equipment.

FIG. **6**C shows screens relating to learning algorithms, in the case such algorithms are being used. In screen **630** the user is informed that their subsequent manual temperature adjustments will be used to train or "teach" the thermostat. In screen **632**, the user is asked to select between whether the thermostat **300** should enter into a heating mode (for example, if it is currently winter time) or a cooling mode (for example, if it is currently summer time). If "COOLING" is selected, then in screen **636** the user is asked to set the "away" cooling temperature, that is, a low-energy-using cooling temperature that should be maintained when the home or business is unoccupied, in order to save energy and/or money. According to some embodiments, the default value offered to the user is 80 degrees F., the maximum value selectable by the user is 90 degrees F., the minimum value selectable is 75 degrees F., and a "leaf" (or other suitable indicator) is displayed when the user selects a value of at least 83 degrees F. Screen **640** shows an example of the display shown when the user is going to select 80 degrees F. (no leaf is displayed), while screen **638** shows an example of the display shown when the user is going to select 84 degrees F. According to some embodiments, a schedule is then created while the screen **642** is displayed to the user.

If the user selects "HEATING" at screen **632**, then in screen **644** the user is asked to set a low-energy-using "away" heating temperature that should be maintained when the home or business is unoccupied. According to some embodiments the default value offered to the user is 65 degrees F., the maximum value selectable by the user is 75 degrees F., the minimum value selectable is 55 degrees F., and a "leaf" (or other suitable energy-savings-encouragement indicator) is displayed when the user selects a value below 63 degrees F. Screens **646** and **648** show examples of the user inputting 63

and 62 degrees respectively. According to some embodiments, a schedule is then created while the screen **642** is displayed to the user.

FIG. **6**D shows certain setup screens, according to some preferred embodiments. According to some embodiments, screen **650** displays the first three setup steps completed, and a fourth step, "Temperature" that has not yet been completed. If "TEMPERATURE" is selected, then in screen **652**, the user is asked if heating or cooling is currently being used at this time of year. In screen **654**, the user is asked to input the energy saving heating and cooling temperatures to be maintained in the case the home or business is unoccupied.

FIGS. **7**A-**7**K show aspects of a general layout of a graphical user interface for a thermostat, according to some embodiments. The screens shown, according to some embodiments, are displayed on a thermostat **300** on round dot-matrix electronic display **316** having a rotatable ring **312** such as shown and described in FIGS. **3**A-**4**. FIG. **7**A shows a basic thermostat screen **700** in heating mode. According to some embodiments, the foreground symbols and characters remain a constant color such as white, while the background color of the screen can vary according to thermostat and HVAC system function to provide an intuitive visual indication thereof. For example, according to a preferred embodiment, a background orange-red color (e.g. R/G/B values: 231/68/0) is used to indicate that the thermostat is currently calling for heating from the HVAC system, and a background blueish color (e.g., R/G/B values: 0/65/226) is used to indicate that the thermostat is currently calling for cooling from the HVAC system. Further, according to some embodiments, the intensity, hue, saturation, opacity or transparency of the background color can be changed to indicate how much heating and/or cooling will be required (or how "hard" the HVAC system will have to work) to achieve the current setpoint. For example, according to some preferred embodiments, a black background is used when the HVAC system is not activated (i.e., when neither heating or cooling is being called for), while a selected background color that represents heat (e.g., orange, red, or reddish-orange) is used if the setpoint temperature is at least 5 degrees F. higher than the current ambient temperature, and while a selected background color that represents cooling (e.g., blue) is used if the setpoint temperature is at least 5 degrees F. lower than the current ambient temperature. Further, according to preferred embodiments, the color can be faded or transitioned between the neutral color (black) and the HVAC active color (red-orange for heating or blue for cooling) to indicate the increasing amount of "work" the HVAC system must do to change the ambient temperature to reach the current setpoint. For example, according to some preferred embodiments, decreasing levels of transparency (i.e., an increasing visibility or "loudness" of the HVAC active color) are used to correspond to increasing discrepancy between the current ambient temperature and the setpoint temperature. Thus, as the discrepancy between the setpoint temperature and the current ambient temperature increases from 1 to 5 degrees, the "loudness" of the background HVAC active color increases from an almost completely transparent overlay on the black background to a completely non-transparent "loud" heating or cooling color. It has been found that the use of variations in color display, such as described, can be extremely useful in giving the user a "feel" for the amount of work, and therefore the amount of energy and cost, that is going to be expended by the HVAC system at the currently displayed setpoint value. This, in turn, can be extremely useful in saving energy, particularly when the user is manually adjusting the setpoint temperature in real time, because the background color provides an immediate feedback relating to the energy consequences of the user's temperature setting behavior.

According to some alternate embodiments, parameters other than simply the difference in current to setpoint temperature can be used in displaying background colors and intensity. For example, time-to-temp (the estimated amount of time it will take to reach the current setpoint temperature), amount of energy, and/or cost, if accurately known can also be used alone or in combination determine which color and how intense (or opaque) is used for the background of the thermostat display.

According to some preferred embodiments the characters and other graphics are mainly displayed in white overlying the black, orange or blue backgrounds as described above. Other colors for certain displayed features, such green for the "leaf" logo are also used according to some embodiments. Although many of the screens shown and described herein are provided in the accompanying drawings with black characters and graphics overlaying a white background for purposes of clarity and print reproduction, it is to be understood that the use of white or colored graphics and characters over black and colored backgrounds such is generally preferable for enhancing the user experience, particularly for embodiments where the electronic display **316** is a backlit dot matrix LCD display similar to those used on handheld smartphones and touchpad computers. Notably, although the presently described color schemes have been found to be particularly effective, it is to be appreciated that the scope of the present teachings is not necessarily so limited, and that other impactful schemes could be developed for other types of known or hereinafter developed electronic display technologies (e.g., e-ink, electronic paper displays, organic LED displays, etc.) in view of the present description without departing from the scope of the present teachings.

In FIG. **7**A, screen **700** has a red-orange background color with white central numerals **720** indicating the current setpoint of 72 degrees F. The current setpoint of 72 degrees is also shown by the large tick mark **714**. The current ambient temperature is 70 degrees as shown by the small numerals **718** and the tick mark **716**. Other tick marks in a circular arrangement are shown in a more transparent (or more muted) white color, to give the user a sense of the range of adjustments and temperatures, in keeping with the circular design of the thermostat, display area and rotatable ring. According to some embodiments, the circular arrangement of background tick marks are sized and spaced apart so that 180 tick marks would complete a circle, but 40 tick marks are skipped at the bottom, such that a maximum of 140 tick marks are displayed. The setpoint tick mark **714** and the current temperature tick mark **716** may replace some the of the background tick marks such that not all of the background tick marks are displayed. Additionally, the current temperature is displayed numerically using numerals **718** which can also be overlaid, or displayed in muted or transparent fashion over the background tick marks. According to some embodiments, so as to accentuate visibility the setpoint tick mark **714** is displayed in 100% opacity (or 0% transparency), is sized such that it extends 20% farther towards the display center than the background tick marks, and is further emphasized by the adjacent background tick marks not being displayed. According to some embodiments, a time-to-temperature display **722** is used to indicate the estimated time needed to reach the current setpoint, as is described more fully co-pending commonly assigned patent application U.S. Ser. No. 12/984,602. FIG. **7**B shows a screen **701**, which displays a "HEAT TO" message **724** indicating that the HVAC system is in heating mode,

although currently is not active ("HEATING" will be displayed when the HVAC system is active). According to some embodiments, the background color of screen **701** is a neutral color such as black. A fan logo **730** can be displayed indicating the fan is active without any associated heating or cooling. Further, a lock icon **732** can be displayed when the thermostat is locked. FIG. **7**C shows a screen **702** which has the message **726** "COOLING" indicating that cooling is being called for, in addition to a background color such as blue. In this case, the message **726** "COOLING" is displayed instead of the time-to-temp display since there may be low confidence in the time-to-temp number may (such as due to insufficient data for a more accurate estimation). In FIG. **7**D, screen **703** shows an example similar to screen **702**, but with the time-to-temp **728** displayed instead of message **726**, indicating that there is a higher confidence in the time-to-temp estimation. Note that the background color of screen **702** and **703** are bluish so as to indicate HVAC cooling is active, although the color may be partially muted or partially transparent since the current setpoint temperature and current ambient temperature is relatively close.

According to some embodiments, to facilitate the protection of compressor equipment from damage, such as with conventional cooling compressors or with heat pump heating compressors, the thermostat prevents re-activation of a compressor within a specified time period ("lockout period") from de-activation, so as to avoid compressor damage that can occur if the de-activation to re-activation interval is too short. For example, the thermostat can be programmed to prevent re-activation of the compressor within a lockout interval of 2 minutes after de-activation, regardless of what happens with the current ambient temperature and/or current setpoint temperature within that lockout interval. Longer or shorter lockout periods can be provided, with 2 minutes being just one example of a typical lockout period. During this lockout period, according to some embodiments, a message such as message **762** in screen **704** of FIG. **7**E is displayed, which provides a visually observable countdown until the end of the lockout interval, so as to keep the user informed and avoid confusion on the user's part as to why the compressor has not yet started up again.

According to some embodiments, a manual setpoint change will be active until an effective time of the next programmed setpoint. For example, if at 2:38 PM the user walks up to the thermostat **300** and rotates the outer ring **312** (see FIG. **3**A, supra) to manually adjust the setpoint to 68 degrees F., and if the thermostat **300** has a programmed schedule containing a setpoint that is supposed to take effect at 4:30 PM with a setpoint temperature that is different than 68 degrees F., then the manual setpoint temperature change will only be effective until 4:30 PM. According to some embodiments, a message such as message **766** ("till 4:30 PM") will be displayed on screen **705** in FIG. **7**F, which informs the user that their setpoint of 68 degrees F. will be in effect until 4:30 PM.

FIG. **7**G shows an example screen **706** in which a message "HEAT TO" is displayed, which indicates that the thermostat **300** is in heating mode but that the heating system is not currently active (i.e., heat is not being called for by the thermostat). In this example, the current temperature, 70 degrees F., is already higher than the setpoint of 68 degrees F., so an active heating call is not necessary. Note that screen **706** is shown with a black background with white characters and graphics, to show an example of the preferred color scheme. FIG. **7**H shows an example screen **707** in which a message **724** "COOL TO" is displayed, which indicates that the cooling system is in cooling mode but is not currently active (i.e. cooling is not being called for by the thermostat). In this example, the current temperature, 70 degrees F., is already lower than the setpoint of 68 degrees F., so an active cooling call is not necessary. This case is analogous to FIG. **7**G except that the system is in cooling mode.

FIG. **7**I shows an example screen **708** where the thermostat has manually been set to "AWAY" mode (e.g., the user has walked up to the thermostat dial and invoked an "AWAY" state using user interface features to be described further infra), which can be performed by the user when a period of expected non-occupancy is about to occur. The display **708** includes a large "AWAY" icon or text indicator **750** along with a leaf icon **740**. Note that the current temperature numerals **718** and tick mark **716** continue to be displayed. During the away mode, the thermostat uses an energy-saving setpoint according to default or user-input values (see, for example, screens **638** and **648** of FIG. **6**C and screen **654** of FIG. **6**D, supra). According to some embodiments, if the user manually initiates an "away" mode (as opposed to the thermostat automatically detecting non-occupancy) then the thermostat will only come out of "away" mode by an explicit manual user input, such as by manually using the user interface. In other words, when manual "away" mode is activated by the user, then the thermostat will not use "auto arrival" to return to standard operation, but rather the user must manually establish his/her re-arrival. In contrast, when the thermostat has automatically entered into an away state based on occupancy sensor data that indicates non-occupancy for a certain period of time (see FIG. **7**J and accompanying text below), then the thermostat will exit the "away" state based on either of (i) occupancy sensor data indicating that occupants have returned, or (ii) an explicit manual user input.

FIG. **7**J shows an example screen **709** where the thermostat has automatically entered into an "AWAY" mode (referred to as "AUTO AWAY" mode), as indicated by the message **752** and icon **750**, based on an automatically sensed state of non-occupancy for a certain period of time. Note that according to some embodiments, the leaf icon **740** is always displayed during away modes (auto or manual) to indicate that the away modes are energy-saving modes. Such display of leaf icon **740** has been found advantageous at this point, because it is reassuring to the user that something green, something good, something positive and beneficial, is going on in terms of energy-savings by virtue of the "away" display. According to some embodiments, the leaf icon **740** is also displayed when the thermostat is in an "OFF" mode, such as shown in example screen **710** in FIG. **7**K, because energy is inherently being saved through non-use of the HVAC system. Notably, the "OFF" mode is actually one of the working, operational modes of the thermostat **300**, and is to be distinguished from a non-operational or "dead" state of the thermostat **300**. In the "OFF" mode, the thermostat **300** will still acquire sensor data, communicate wirelessly with a central server, and so forth, but will simply not send heating or cooling calls (or other operating calls such as humidification or dehumidification) to the HVAC system. The "OFF" mode can be invoked responsive to an explicit menu selection by the user, either through the rotatable ring **312** (see screen **814** of FIG. **8**C, infra), or from a network command received via the Wi-Fi capability from a cloud-based server that provides a web browser screen or smartphone user interface to the user and receives an OFF command thereby. As illustrated in FIG. **7**K, the current temperature numerals **718** and current temperature tick mark **716** are preferably displayed along with the leaf **740** when the thermostat is in "OFF" mode. In alternative embodiments, background tick marks can also be displayed in "OFF" mode.

According to a preferred embodiment, all of the operational screens of the thermostat **300** described herein that correspond to normal everyday operations, such as the screens of FIGS. **7**A-**7**K, will actually only appear when the proximity sensor **370**A (see FIG. **3**A, supra) indicates the presence of a user or occupant in relatively close proximity (e.g., 50 cm-200 cm or closer) to the thermostat **300**, and the electronic display **316** will otherwise be dark. While the user is proximal to the thermostat **300** the electronic display **316** will remain active, and when the user walks away out of proximity the electronic display **316** will remain active for a predetermined period of time, such as 20 seconds, and then will go dark. In contrast to an alternative of keeping the electronic display **316** active all of the time, this selective turn-on and turn-off of the electronic display has been found to be a preferable method of operation for several reasons, including the savings of electrical power that would otherwise be needed for an always-on electronic display **316**, extension of the hardware life of the electronic display **316**, and also aesthetic reasons for domestic installations. The savings of electrical power is particularly advantageous for installations in which there is no "C" wire provided by the HVAC system, since it will often be the case that the average power that can safely obtained from power-stealing methods will be less than the average power used by a visually pleasing hardware implementation of the electronic display **316** when active. Advantageously, by designing the thermostat **300** with the rechargeable battery **482** and programming its operation such that the electronic display **316** will only be active when there is a proximal viewer, the electronic display **316** itself can be selected and sized to be bright, bold, informative, and visually pleasing, even where such operation takes more instantaneous average electrical power than the power stealing can provide, because the rechargeable battery **482** can be used to provide the excess power needed for active display, and then can be recharged during periods of lesser power usage when the display is not active. This is to be contrasted with many known prior art electronic thermostats whose displays are made very low-power and less visually pleasing in order to keep the thermostat's instantaneous power usage at budget power-stealing levels. Notably, it is also consistent with the aesthetics of many home environments not to have a bright and bold display on at all times, such as for cases in which the thermostat is located in a bedroom, or in a media viewing room such as a television room. The screens of FIGS. **7**A-**7**K can be considered as the "main" display for thermostat **300** in that these are the screens that are most often shown to the user as they walk up to the thermostat **300** in correspondence with normal everyday operation.

According to one embodiment, the thermostat **300** is programmed and configured such that, upon the detection of a working "C" wire at device installation and setup, the user is automatically provided with a menu choice during the setup interview (and then revised later at any time through the settings menu) whether they would like the electronic display **316** to be on all the time, or only upon detection of a proximal user. If a "C" wire is not detected, that menu choice is not provided. A variety of alternative display activation choices can also be provided, such as allowing the user to set an active-display timeout interval (e.g., how long the display remains active after the user has walked away), allowing the user to choose a functionality similar to night lighting or safety lighting (i.e., upon detection of darkness in the room by the ambient light sensor **370**B, the display will be always-on), and other useful functionalities. According to yet another embodiment, if the presence of a "C" wire is not detected, the thermostat **300** will automatically test the power stealing circuitry to see how much power can be tapped without tripping the call relay(s), and if that amount is greater than a certain threshold, then the display activation menu choices are provided, but if that amount is less than the certain threshold, the display activation menu choices are not provided.

FIGS. **8**A-C show example screens of a rotating main menu, according to some preferred embodiments. The screens shown, according to some embodiments, are displayed on a thermostat **300** on a round dot-matrix electronic display **316** having a rotatable ring **312** such as shown and described in FIGS. **3**A-**4**. FIG. **8**A shows an example screen **800** in normal operations (such as described in FIG. **7**A or **7**C). An inward click from the normal display screen **800** causes a circumferential main menu **820** to appear as shown in screen **801**. In this example the main menu **820** displays about the perimeter of the circular display area various menu names such as "SETTINGS," "ENERGY," "SCHEDULE," "AWAY," "DONE," as well one or more icons. The top of the circular menu **820** includes an active window **822** that shows the user which menu item will be selected if an inward click is performed at that time. Upon user rotation of the rotatable ring **312** (see FIG. **3**A, supra) the menu items turn clockwise or counter clockwise, matching the direction of the rotatable ring **312**, so as to allow different menu items to be selected. For example, screen **802** and **804** show examples displayed in response to a clockwise rotation of the rotatable ring **312**. One example of a rotating menu that rotates responsive to ring rotations according to some embodiments is illustrated in the commonly assigned U.S. Ser. No. 29/399,632, supra. From screen **804**, if an inward click is performed by the user, then the Settings menu is entered. It has been found that a circular rotating menu such as shown, when combined with a rotatable ring and round display area, allows for highly intuitive and easy input, and so therefore greatly enhances the user interface experience for many users. FIG. **8**B shows an example screen **806** that allows for the schedule mode to be entered. FIG. **8**C shows the selection of a mode icon **809** representing a heating/cooling/off mode screen, the mode icon **809** comprising two disks **810** and **812** and causing the display of a mode menu if it appears in the active window **822** when the user makes an inward click. In screen **808**, a small blue disk **810** represents cooling mode and a small orange-red disk **812** represents heating mode. According to some embodiments the colors of the disks **810** and **812** match the background colors used for the thermostat as described with respect to FIG. **7**A. One of the disks, in this case the heating disk **812** is highlighted with a colored outline, to indicate the current operating mode (i.e. heating or cooling) of the thermostat. In one alternative embodiment, the mode icon **809** can be replaced with the text string "HEAT/COOL/OFF" or simply the word "MODE". If in inward click is performed from screen **808**, a menu screen **814** appears (e.g. using a "coin flip" transition). In screen **814** the user can view the current mode (marked with a check mark) and select another mode, such as "COOL" or "OFF." If "COOL" is selected then the thermostat will change over to cooling mode (such changeover as might be performed in the springtime), and the cooling disk icon will highlighted on screens **814** and **808**. The menu can also be used to turn the thermostat off by selecting "OFF." In cases the connected HVAC system only has heating or cooling but not both, the words "HEAT" or "COOL" or "OFF" are displayed on the menu **820** instead of the colored disks.

FIGS. **9**A-J and **10**A-I illustrate example user interface screens for making various settings, according to some embodiments. The screens shown, according to some embodiments, are displayed on a thermostat **300** on round

dot-matrix electronic display **316** having a rotatable ring **312** such as shown and described in FIGS. **3A-4**. In FIG. **9**A, screen **900** is initially displayed following a user selection of "SETTINGS" from the main menu, such as shown in screen **804** of FIG. **8**A. The general layout of the settings menu in this example is a series of sub-menus that are navigated using the rotatable ring **312**. For example, with reference to FIG. **9**A, the user can cause the initial screen **900** to be shifted or translated to the left by a clockwise rotation of the rotatable ring **312**, as shown in the succession of screens **902** and **908**. The animated translation or shifting effect is illustrated in FIG. **9**A by virtue of a portion of the previous screen disk **901** and a portion of the new screen disk **906** shifting as shown, and is similar to the animated shifting translation illustrated in the commonly assigned U.S. Ser. No. 29/399,621, supra. Further rotation of the ring leads to successive sub-menu items such as "system on" screen **912**, and lock setting screen **916** (see FIG. **9**B). Rotating the ring in the opposite direction, i.e., counterclockwise, translates or shifts the screens in the opposite direction (e.g., from **916** to **908** to **900**). The "initial screen" **900** is thus also used as a way to exit the settings menu by an inward click. This exit function is also identified by the "DONE" label on the screen **900**. Note that inner disk **901** shows the large central numerals that correspond to the current setpoint temperature and can include a background color to match the thermostat background color scheme as described with respect to FIG. **7**A, so as to indicate to a user, in an intuitive way, that this screen **900** is a way of exiting the menu and going "back" to the main thermostat display, such as shown in FIGS. **7**A-K. According to some embodiments, another initial/done screen such as screen **900** is displayed at the other end (the far end) of the settings menu, so as to allow means of exit from the settings menu from either end. According to some embodiments, the sub-menus are repeated with continued rotation in one direction, so that they cycle through in a circular fashion and thus any sub menu can eventually be accessed by rotating the ring continuously in either one of the two directions.

Screen **908** has a central disk **906** indicating the name of the sub-menu, in this case the Fan mode. Some sub menus only contain a few options which can be selected or toggled among by inward clicking alone. For example, the Fan sub-menu **908** only has two settings "automatic" (shown in screen **908**) and "always on" (shown in screen **910**). In this case the fan mode is changed by inward clicking, which simply toggles between the two available options. Ring rotation shifts to the next (or previous) settings sub-menu item. Thus rotating the ring from the fan sub-menu shift to the system on/off sub-menu shown in screens **912** (in the case of system "ON") and **914** (in the case of system "OFF"). The system on/off sub-menu is another example of simply toggling between the two available options using the inward click user input.

In FIG. **9**B, screen **916** is the top level of the lock sub-menu. If the thermostat is connected and paired (i.e., has Internet access and is appropriately paired with a user account on a cloud-based server), an inward click will lead to screen **918**. At screen **918**, the user can vary the highlighting between the displayed selections by rotating the rotatable ring **312**, and then can select the currently displayed menu item by inward clicking the rotatable ring **312**. If "LOCKED" is selected then the user is asked to enter a locking PIN in screen **920**. If the thermostat is already locked then screen **925** is displayed instead of screen **916**. If the thermostat is unlocked then a PIN confirmation is requested such as in screen **922**. If the confirmation PIN does not match then the user is asked to enter a new PIN in screen **924**. If the confirmation PIN matches, then the temperature limits are set in screens **938** and/or **939** in FIG. **9**C. The described locking capability can be useful in a variety of contexts, such as where a parent desires the limit the ability of their teenager to set the temperature too high in winter or too low in summer. According to some embodiments, locking of the thermostat is not permitted if the thermostat is not connected to the Internet or is not paired to an account, so that an online backup method of unlocking the thermostat is available should the user forget the PIN number. In such case, if the thermostat is not connected to the Internet, then screen **926** is displayed, and if the thermostat is not paired then screen **927** is displayed.

FIG. **9**C shows further details of the locking feature, according to some embodiments. In screen **938** the user is allowed to set the minimum setpoint temperature using the rotatable ring followed by an inward click (in the case where a cooling system is present). Screen **939** similarly allows the user to set the maximum setpoint temperature (when a heating system is present). After setting the limits in screens **938** and/or **939** a coin flip transition returns to the main thermostat operation screen such as shown in screen **940**. In the case shown in screen **940**, a maximum setpoint of 73 degrees F. has been input. A lock icon **946** is displayed on the dial to notify the user that a maximum setpoint temperature has been set for the heating system. Screens **941**, **942**, **943**, **944** and **945** show the behavior of the thermostat when locked, according to some embodiments. In this example, the user is trying to adjust the setpoint temperature above the maximum of 73 degrees. In screen **943** the user is asked for the PIN. If the PIN is incorrect, then the thermostat remains locked as shown in screen **944**. If the PIN is correct the thermostat is unlocked and lock icon is removed as shown in screen **945**, in which case the user can then proceed to change the current setpoint above 73 degrees F.

FIG. **9**D shows a sub-menu for settings and information relating to learning, according to some preferred embodiments. Screen **928** displays a learning sub-menu disk **928***a* which, when entered into by inward clicking, leads to screen **929**. From screen **929** four different options can be selected. If "SCHEDULE learning" is selected, then in screen **930** the user is notified of how long the learning algorithm has been active (in the example shown, learning has been active for three days). If the user selects "PAUSE LEARNING" then learning is paused, which is reflected in the screen **931**. If the user selects "AUTO-AWAY training" then the user is notified of the auto-away function in screen **932**. By clicking to continue, the user is asked if the auto away feature should be active in screen **933**. If the user selects "SET TEMP." then in screen **934** the user can input the energy-saving temperatures to be used when the home or business is non-occupied, these temperatures being applicable upon either an automatically invoked or a manually invoked away condition. In an alternative embodiment (not shown), the user is able to enter different temperature limits for the automatically invoked away condition versus the manually invoked away condition. According to some embodiments an energy saving icon, such as the leaf icon, is displayed next to the temperatures in screen **934** if those selected temperatures conforms to energy-saving standards or other desirable energy-saving behavior. If the user selects "YES" from screen **933** then the user is notified of the confidence status of the activity/occupancy sensor used for automated auto-away invocation. Screen **935** is an example showing that the activity sensor confidence is too low for the auto-away feature (the automated auto-away invocation) based on to be effective. Screen **937** is an example of a screen shown when the activity/occupancy sensor is "in training" and the progress in percentage is displayed. If and when the activity/occupancy sensor confidence is high

enough for the auto-away function to be effective, then another message (not shown) is displayed to notify the user of such. Screen **936** is an example of information displayed to the user pertaining to the leaf icon and is accessed by selecting the leaf icon from the screen **929**.

FIG. **9**E shows settings sub-menus for learning and for auto-away, according to some alternate embodiments. Screens **950**-**958** show alternative screens to those shown in FIG. **9**D. Upon clicking at the screen **950**, in screen **951** the user is asked if learning should be activated based on the user's adjustments, and if yes, then in screen **952** the user is informed that the thermostat will automatically adjust the program schedule based on the user's manual temperature adjustments. In screen **953** the user is notified of how long the learning feature has been active (if applicable). In screen **954** the user is notified that learning cannot be activated due to a conflict with another setting (in this case, the use of a RANGE mode of operation in which both upper and lower setpoint temperatures are enforced by the thermostat).

Upon user ring rotation at screen **950**, screen **955** is displayed which allows entry to the auto-away sub-menu. Screen **956** asks if the auto-away feature should be active. Screen **957** notifies the user about the auto-away feature. Screen **958** is an example showing the user the status of training and/or confidence in the occupancy sensors. Other examples instead of screen **958** include "TOO LOW FOR AUTO-AWAY" and "ENOUGH FOR AUTO-AWAY," as appropriate.

FIG. **9**F shows sub-menu screen examples for settings for brightness, click sounds and Celsius/Fahrenheit units, according to some embodiments. Screens **960**, **961**, **962** and **963** toggle among four different brightness settings using the inward click input as shown in FIG. **9**F. Specifically, the settings for auto-brightness, low, medium and high can be selected. According to some embodiments, the brightness of the display is changed to match the current selection so as to aid the user in selecting an appropriate brightness setting. Screens **964** and **965** toggle between providing, and not providing, audible clicking sounds as the user rotates the rotatable ring **312**, which is a form of sensory feedback that some users prefer and other users do not prefer. Screens **966** and **967** are used to toggle between Celsius and Fahrenheit units, according to some embodiments. According to some embodiments, if Celsius units is selected, then half-degrees are displayed by the thermostat when numerical temperature is provided (for example, a succession of 21, 21^5, 22, 22^5, 23, 23^5, and so forth in an example in which the user is turning up the rotatable ring on the main thermostat display). According to another embodiment, there is another sub-menu screen disk (not shown) that is equivalent to the "Brightness" and "Click Sound" disks in the menu hierarchy, and which bears one of the two labels "SCREEN ON when you approach" and "SCREEN ON when you press," the user being able to toggle between these two options by an inward click when this disk is displayed. When the "SCREEN ON when you approach" is active, the proximity sensor-based activation of the electronic display screen **316** is provided (as described above with the description accompanying FIG. **8**C), whereas when the "SCREEN ON when you press" option is selected, the electronic display screen **316** does not turn on unless there is a ring rotation or inward click.

FIG. **9**G shows a sub menu for entering or modifying a name for the thermostat, according to some embodiments. Clicking on screen **968** leads to either screen **969** in the case of a home installation or screen **970** in the case of a business installation. In screens **969** and **970** several common names are offered, along with the option of entering a custom name. If "TYPE NAME" is selected from either screen a character input interface **971** is presented through which the user can enter a custom name. The newly selected (or inputted) name for the thermostat is displayed in the central disk as shown in screen **972**.

FIG. **9**H shows sub-menu screens relating to network connection, according to some embodiments. In FIG. **9**H, screen **974** shows a network sub menu disk **974***a* showing the current connected network name, in this case "Network2." The wireless symbol next to the network name indicates that the wireless connection to that network is currently active. Clicking leads to screen **975** which allows the user to select a different wireless network if available (in this case there is another available network called "Network3"), disconnect or obtain technical network details. If "TECH. DETAILS" is selected then screen **976** is displayed which, by scrolling using the rotatable ring **312**, the user can view various technical network details such as shown in the list **977**. If a different network is selected from screen **975**, then the user is prompted to enter a security password (if applicable) using interface **978**, after which a connection attempt is made while screen **979** is displayed. If the connection is successful, then screen **980** is displayed.

FIG. **10**A shows settings screens relating to location and time, according to some embodiments. Screen **1000** shows a sub-menu disk **1000***a* having the currently assigned zip code (or postal code). Clicking leads to screen **1002** for selecting the country. Selecting the country (e.g. "USA") provides the appropriate ZIP code/postal code format for the following screen. In this case "USA" is selected and the ZIP code is entered on screens **1004** and **1006**. Screen **1008** shows a sub-menu disk **1008***a* having the current time and date. Clicking when the thermostat is connected to the Internet and in communication with the associated cloud-based server automatically sets the time and date as shown in screen **1010**. If the thermostat is not connected to the Internet, clicking leads to screen **1012** in which the user can manually enter the time, date and daylight savings time information.

FIG. **10**B shows settings screens relating to technical and legal information, according to some embodiments. Screen **1014** shows a sub-menu disk **1014***a* bearing the TECHNICAL INFO moniker, whereupon clicking on screen **1014** leads to screen **1016** which displays a long list **1018** of technical information which is viewed by scrolling via the rotatable ring **312**. Similarly, screen **1020** shows a sub-menu disk **1020***a* bearing the LEGAL INFO moniker, whereupon clicking on screen **1020** leads to screen **1022** which displays various legal information.

FIGS. **10**C and **10**D show settings screens relating to wiring and installation, according to some embodiments. In FIG. **10**C, screen **1024** shows a sub-menu disk **1024***a* the provides entry to the wiring settings sub-menu. If no wiring warnings or errors are detected then the wiring is considered "good wiring" and a click displays screen **1026** which shows the connection terminals having the wires connected and the HVAC functionality related to each. This screen is analogous to screen **574** shown in FIG. **5**E. According to some embodiments, the wiring and installation settings sub-menu can also perform testing. For example, screen **1028** asks the user if an automatic test of the heating and cooling equipment should be undertaken. Screen **1029** shows an example screen during the automatic testing process when the first item, the fan, is being tested. If the fan test returns satisfactory results (screen **1030**) the next testing step is carried out, in this case cooling, with a checkmark next to the word "Fan" notifying the user of the successful completion of the fan test. Screen **1032** shows an example screen where all of the automatic tests have been successfully completed (for an installation that includes a fan,

heating, cooling and auxiliary heating). Screen **1034** shows an example of a failed automatic test, in this case the fan test, and asks the user if a wiring change should be made. In screen **1036** the user can elect to continue with the other testing steps, and screen **1038** shows an example of the completion of the testing where one of the steps had an error or test failure (in this case the fan test).

In FIG. **10**D, screen **1040** shows an example of a wiring warning, which is denoted by a yellow or otherwise highlighted disk next to the connector terminal label "cool". An inward click input leads to an explanation of the warning, in this case being an error in which there is a wire insertion detected at terminal Y1 but no electronic signature consistent with a cooling system can be sensed. Note that the wiring warning shown in this example is not serious enough to block operation. However, some wiring errors are serious enough such that HVAC operation is blocked. An example is shown in screen **1044** where the wires are detected on the C and Rc terminals but no power is detected. A red disk appears next to the terminal connected labeled "cool" which indicates a wiring error. Clicking leads to an explanation screen **1046** and a notification screen **1048**, followed by a mandatory thermostat shut down (blank screen **1050**). Examples of detected wiring warnings that do not block operation, and wiring errors that block operation, are discussed supra with respect to FIG. **5**E.

FIGS. **10**E and **10**F show screens relating to certain advanced settings, according to some embodiments. Screen **1052** shows entry to the advanced settings sub-menu. Inward clicking on the sub-menu disk at screen **1052** leads to an advanced settings sub-menu selection screen **1054**. Selecting "EQUIPMENT" leads to some advanced equipment related settings. For example, screens **1055**, **1056** and **1057** allow the user to activate pre-heating or pre-cooling, according to what type of equipment is installed. Selecting "SAFETY TEMP." from screen **1054** leads to screens **1059**, **1060** and **1061** that allow settings for safety temperatures, which are minimum and maximum temperatures that will be maintained so long as the thermostat is operational. Safety temperatures can be useful, for example, to prevent damage such as frozen pipes, due to extreme temperatures. Selecting "HEAT PUMP" leads to screen **1062** in FIG. **10**F. Note that according to some preferred embodiments, the heat pump option in screen **1054** will only appear if a heat pump is installed. Screens **1062**, **1063** and **1064** allow settings for heat pump and auxiliary heating configurations. Since heat pump effectiveness decreases with decreasing outside temperature, the user is provided with an option at screen **1063** to not invoke the heat pump below a selected outside temperature. Since auxiliary resistive electric heating is very energy intensive, the user is provided with an option at screen **1064** to not invoke the auxiliary heat above a selected outside temperature. By lowering the temperature in screen **1064**, the user can save auxiliary heating energy that might otherwise be used simply to speed up the heating being provided by the slower, but more energy-efficient, heat pump. For some embodiments, the real-time or near-real-time outside temperature is provided to the thermostat **300** by the cloud-based server based on the ZIP code or postal code of the dwelling. Selecting "RANGE" from screen **1054** leads to temperature range settings screens **1065**, **1066**, **1067** and **1068**. The user is warned that enabling temperature ranges can use high levels of energy and that automatic learning has to be disabled. Screens **1070** and **1071** show examples of questions to ascertain the type of heating system installed.

FIGS. **10**G, **10**H and **10**I show screens relating to resetting the thermostat, according to some embodiments. Screen **1072** shows entry into the reset settings sub-menu. If learning is currently active, clicking at screen **1072** leads to screen **1073**. If "LEARNING" is selected, then in screens **1074**, **1075** and **1076** the user can reset the learning so as to erase the current schedule and learning data. Note that screen **1075** provides a way of confirming the user's agreement with the procedure (which includes forgetting the data learned up until the present time) by asking the user to rotate the rotatable ring to that the large tick mark moves through the background tick-arc as shown. Further, the user in screen **1076** is given a time interval, in this case 10 seconds, in which to cancel the learning reset process. The reset dial and the cancellation interval effectively reduce the risk of the user inadvertently performing certain reset operations involving learned data loss. Selecting "DEFAULTS" from screen **1073** leads to screens **1077**, **1078**, **1079** and **1080** which erases all information from the unit and returns the thermostat unit to factory defaults. This operation could be useful, for example if the user wishes to sell the unit to someone else. If learning is not active when screen **1072** is clicked, then screen **1082** is displayed instead of screen **1073**. Selecting "SCHEDULE" at screen **1082** leads to screens **1083**, **1084** and **1085** which allow the user to reset the current schedule information. Selecting "RESTART" leads to screens **1086** and **1087** in which the user can re-boot the thermostat, again providing some protection against unintended data loss (in this case, the particular schedule that the user may have taken some time to establish).

FIG. **10**I shows example screens following a reset operation. If the reset operation erased the information about home or business installation then screen **1088** can be displayed to obtain this setting. According to some embodiments basic questions are used to establish a basic schedule. Example questions **1090** are for a home installation, and example questions **1092** are for a business installation. Screens **1094** and **1095** show further screens in preparing a basic schedule. Screen **1096** shows the final settings screen, which is reachable by rotating the ring from screen **1072**, allowing for a way for the user to exit the settings menu and return to standard thermostat operation. According to some embodiments, one or more other "exit" methods can be provided, such as clicking and holding to exit the settings menus.

FIGS. **11**A-D show example screens for various error conditions, according to some embodiments. The screens shown, according to some embodiments, are displayed on a thermostat **300** on round dot-matrix electronic display **316** having a rotatable ring **312** such as shown and described in FIGS. **3**A-**4**. In FIG. **11**A, screens **1100**, **1101**, **1103**, **1104** and **1105** show an example of a power wiring error. A red disk next to the power connector terminal label in screen **1100** shows the there is a power wire related error. Clicking leads to screen **1101** that explains the wiring error condition, including an error number associated with the error. Screen **1103** instructs the user to remove the thermostat head unit from the back-plate and to make corrective wiring connections, if possible. Screen **1104** is displayed while the thermostat is performing a test of the wiring condition following re-attachment of the head unit to the back-plate. If the error persists, screen **1105** displays information for the user to obtain technical support, as well as an error number for reference. Screens **1106**, **1107**, **1108** and **1109** show an example for an error where HVAC auto-detection found a problem during its initial automated testing (e.g. performed during the initial installation of the thermostat), such initial automated testing being described, for example, in U.S. Ser. No. 13/038,191, supra. In FIG. **11**B, screens **1110**, **1111**, **1112**, **1113** and **1114** show an example for an error where HVAC auto-detection found a problem during later testing. Screens **1116**, **1117** and **1118** show an example where the head unit (see FIG. **4**, head unit **410**) had

detected that the back-plate (see FIG. **4**, back plate **440**) has failed in some way. In FIG. **11**C, thermostat screens **1120**, **1121**, **1122**, **1123**, **1124** and **1125** show an example of when the head unit detects that it has been attached to a different baseplate than it expects. The user given the option in screen **1120**, to either remove the head unit from the baseplate, or reset the thermostat to its factory default settings. In FIG. **11**D, screens **1130**, **1131**, **1132** and **1133** show an example in which power stealing (or power harvesting) is causing inadvertent tripping or switching of the HVAC function (e.g. heating or cooling). In this case the user is informed that a common wire is required to provide power to the thermostat.

FIGS. **12**A and **12**B show certain aspects of user interface navigation through a multi-day program schedule, according to some preferred embodiments. The screens shown, according to some embodiments, are displayed on a thermostat **300** on round dot-matrix electronic display **316** having a rotatable ring **312** such as shown and described in FIGS. **3**A-**4**. In FIG. **12**A, screen **1200** includes a rotating main menu **820** with an active window **822**, as shown and described with respect to FIG. **8**A. Selecting "SCHEDULE" leads to an animated transition from the rotating main menu screen to a horizontally-oriented week-long schedule viewer/editor. One example of an animated transition from the rotating main menu screen to a horizontally-oriented week-long schedule according to some embodiments is illustrated in the commonly assigned U.S. Ser. No. 29/399,636, supra. Screens **1210**, **1212** and **1214** show portions of the animated transition. Screen **1210** shows a shifting or translation to the schedule display that preferably begins with a removal of the circular main menu (e.g. similar to FIG. **7**A), followed by a shrinking (or zoom-out) of the circular standard thermostat view **1204**. Along with the shrinking, the circular standard view **1204** begins to shift or translate to the left while the rectangular horizontally-oriented week-long schedule **1206** begins to appear from the right as shown in screen **1210**. The week-long schedule begins with Monday, as shown in screen **1212**, and continues to translate to a position that corresponds to the current time and day of the week, which in this example is 2:15 PM on Thursday, which is shown in screen **1214**. The horizontally-oriented schedule has a plot area in which the vertical axis represents the temperature value of the setpoints and the horizontal axis represents the effective time (including the day) of the setpoints. The schedule display includes a day of the week label, labels for each 4 hours (e.g. 12A, 4A, 8A, 12P, 4P, 8P and 12P), a central horizontal cursor bar **1220** marking the current schedule time, as well as a small analog clock **1230** that displays hands indicating the current schedule time. Setpoints are indicated as circles with numbers corresponding to the setpoint temperature, and having a position corresponding to the setpoint temperature and the time that the setpoint becomes effective. According to some embodiments, the setpoint disks are filled with a color that corresponds to heating or cooling (e.g. orange or blue). Additionally, a continuation indicator mark **1222** may be included periodically, for example at each day at midnight, that show the current setpoint temperature at that point in time. The continuation indicator mark can be especially useful, for example, when there are large time gaps between setpoints such that the most recent setpoint (i.e. the active setpoint) may no longer be visible on the current display.

According to some embodiments, timewise navigation within the week-long schedule is accomplished using the rotatable ring **312** (shown in FIG. **3**A). Rotating the ring clockwise shifts the schedule in one direction, such as in screen **1240**, which is moves forward in time (i.e. the schedule plot area shifts to the left relative to the centrally located current schedule time cursor bar **1220**, and the analog clock **1230** spins forward in displayed time). Rotating the ring counter-clockwise does the opposite, as shown in screen **1242**, shifting the schedule backwards in time (i.e. the schedule plot area shifts to the right relative to the centrally located current schedule time cursor bar **1220**, and the analog clock **1230** spins backward in displayed time). According to some preferred embodiments, the schedule time adjustment using the rotatable ring is acceleration-based. That is, the speed that the schedule time is adjusted is based on the speed of rotation of the ring, such that detailed adjustments in the current schedule time can be made by slowly rotating the ring, while shifts from day to day or over multiple days can be made by rapidly rotating the ring. According to some embodiments, the difference in acceleration rate factor is about 4 to 1 between the fastest and slowest rotating speeds to achieve both adequate precision and easy movement between days, or to the end of the week. Screen **1244** shows an example of more rapid movement of the rotatable ring, where the schedule has been shifted at a higher rate factor than in screen **1242**. According to some embodiments the schedule time adjustments are accompanied by audible "click sound" or other noise to provide further feedback and further enhance the user interface experience. According to some preferred embodiments, the audible clicks correspond to each 15 minutes of schedule time that passes the time cursor bar **1220**.

If the time cursor bar **1220** is not positioned on an existing setpoint, such as shown in screen **1214**, and an inward click is received, a create new setpoint option will be offered, as in screen **1250** of FIG. **12**B. In screen **1250**, if the user selects "NEW" then a new setpoint disk **1254** will appear on the time cursor bar **1220**, as shown in screen **1252**. For some embodiments, this "birth" of the new setpoint disk **1254** proceeds by virtue of an animation similar to that illustrated in the commonly assigned U.S. Ser. No. 29/399,637, supra, wherein, as soon as the user clicks on "NEW," a very small disk (much smaller than the disk **1254** at screen **1252**) appears near the top of the cursor bar **1220**, and then progressively grows into its full-size version **1254** as it visibly "slides" downward to "land" at a vertical location corresponding to a starting temperature setpoint value. For some embodiments, the starting temperature setpoint value is equal to that of an immediately preceding setpoint in the schedule. Rotating the ring will then adjust the setpoint temperature of the new setpoint disk **1254** upward or downward from that starting temperature setpoint value. According to some embodiments, an energy savings encouragement indicator, such as the leaf logo **1260**, is displayed when the new setpoint temperature corresponds to energy-saving (and/or cost saving) parameters, which aids the user in making energy-saving decisions. Once the temperature for the new setpoint is satisfactory, an inward click allows adjustment of the setpoint time via the rotatable ring, as shown in screen **1256**. Once the start time for the new setpoint is satisfactory, another inward click establishes the new setpoint, as shown in screen **1258**. If the time cursor bar **1220** is positioned on an existing setpoint, such as shown in screen **1270**, an inward click brings up a menu screen **1272** in which the user can choose to change the setpoint, remove the setpoint or return out of the schedule viewer/editor. If the user selects "CHANGE" then the user can make adjustments to the temperature and start time similar to the methods shown in screens **1252** and **1256**, respectively.

According to some embodiments, setpoints must be created on even quarter-hours (i.e. on the hour, or 15, 30 or 45 minutes past), and two setpoints cannot be created or moved to be less than 60 minutes apart. Although the examples shown herein display a week-long schedule, according to

other embodiments, other time periods can be used for the displayed schedule, such as daily, 3-day, two weeks, etc.

FIG. **13** shows example screens relating to the display of energy usage information, according to some embodiments. The screens shown, according to some embodiments, are displayed on a thermostat **300** on round dot-matrix electronic display **316** having a rotatable ring **312** such as shown and described in FIGS. **3A-4**. From the rotating main menu such as shown in FIG. **8**A, if the "ENERGY" option is selected, an interactive energy information viewer is displayed. According to some embodiments a shrinking and shifting of the standard thermostat display transition is used similar to the transition to the schedule viewer/editor described above. For example, screen **1310** (see upper right side of FIG. **13**) includes a shrunken disk **1302** that corresponds to the current standard thermostat display (such as FIG. **7**A), except that it is reduced in size. Rotating the ring shifts the energy viewer to display energy information for a progression of prior days, each day being represented by a different window or "disk". For example, rotating the ring from the initial position in screen **1310** leads first to screen **1312** (showing energy information for "yesterday"), then to screen **1314** (showing energy information for the day before yesterday), then to screen **1316** (for three days prior), and then to screen **1318** (for four days prior), and so on. Preferably, the shifts between progressive disks representative of respectively progressive time periods proceeds as an animated shifting translation in a manner similar to that described for FIG. **9**A (screens **900-902-908**) and the commonly assigned U.S. Ser. No. 29/399,621, supra. According to some embodiments, the shifting information disks continue for 7 days prior, after which summary information is given for each successive prior week. Shown on each energy information disk is a measure of the amount of energy used relative to an average. For example, in disk **1332** for "yesterday" the energy usage was 4% below average, while in disk **1334** for Sunday September 11 the energy usage was up 2%. Additionally, according to some embodiments, an explanatory icon or logo is displayed where a primary reason for the change in energy usage can be determined (or estimated). For example, in screen **1322** a weather logo **1340** is displayed when the usage change is deemed primarily due to the weather, and an auto-away logo **1342** is displayed when the usage change is deemed primarily due to the auto-away detection and settings. Other logos can be used, for example, to represent changes in usage due to manual setpoint changes by users. Clicking on any of the information disk screens **1312**, **1314** and **1318** lead to more detailed information screens **1322**, **1324** and **1328** respectively.

FIG. **14** shows example screens for displaying an animated tick-sweep, according to some embodiments. The screens shown, according to some embodiments, are displayed on a thermostat **300** on round dot-matrix electronic display **316** having a rotatable ring **312** such as shown and described in FIGS. **3A-4**. An animation is preferably displayed to enhance the user interface experience in which several highlighted background tick marks "sweep" across the space starting at the current temperature tick mark and ending at the setpoint temperature tick mark. One example of an animated tick-sweep according to some embodiments is illustrated in the commonly assigned U.S. Ser. No. 29/399,630, supra. In the case of cooling, shown in successive screens **1410**, **1412**, **1414**, **1416** and **1418**, highlighted background tick marks **1406** "sweep" from the current temperature tick mark **1402** to the setpoint tick mark **73**. In the case of heating, the highlighted background tick marks sweep in the opposite direction.

FIGS. **15**A-C show example screens relating to learning, according to some alternate embodiments. The screens shown, according to some embodiments, are displayed on a thermostat **300** on round dot-matrix electronic display **316** having a rotatable ring **312** such as shown and described in FIGS. **3A-4**. In FIG. **15**A, screens **1500**, **1502** and **1504** display information to a user indicating in general terms how the thermostat will learn from their actions according to some embodiments. During a learning period the thermostat learns from the user's adjustments, according to some embodiments. Screens **1510** to **1512** show a user adjustment to set the setpoint to 75 degrees F. by a ring rotation input. The message "LEARNING" is flashed on and off twice to notify the user that the adjustment is being used to "train" the thermostat. After flashing, the regular message "HEATING" is displayed in screen **1516** (which could also be a time-to-temperature display if confidence is high enough). Screen **1518** is an example of a message reminding the user that the manual setpoint 75 degrees F. will only be effective until 4:15 PM, which can be due, for example, to an automatic setback imposed for training purposes (which urges the user to make another manual setpoint adjustment). In FIG. **15**B, screen **1520** shows an example of a case in which the setpoint temperature has automatically been set back to a low temperature value (in this case 62 degrees) which will encourage the user can make a setpoint change according to his/her preference. Screen **1522** reminds the user that, for the learning algorithm, the user should set the temperature to a comfortable level for the current time of day, which is has been done a shown in screen **1524**. According to some embodiments, during the evening hours the automatic setback to a low temperature (such as 62 degrees F.) is not carried out so as to improve comfort during the night. In screen **1530**, **1532** and **1534**, the temperature in the evening is automatically set to 70 degrees for user comfort. In FIG. **15**C, screen **1540** shows a message informing the user that the initial learning period has completed. Screen **1542** informs the user that the auto-away confidence is suitably high and the auto-away feature is therefore enabled. Screens **1544** and **1546** inform the user that sufficient cooling and heating time calculation confidence has been achieved, respectively, for enabling sufficiently accurate time to temperature calculations, and also to notify the user that, since enough information for suitable energy-saving encouragement using the leaf logo has taken place, the leaf logo will be appearing in ways that encourage energy-saving behavior. Screen **1548** shows a message informing the user that an automatic schedule adjustment has been made due to the learning algorithm.

FIGS. **16**A-**16**B illustrate a thermostat **1600** according to an alternative embodiment having a different form factor that, while not believed to be quite as advantageous and/or elegant as the circular form factors of one or more previously described embodiments, is nevertheless indeed within the scope of the present teachings. Thermostat **1600** comprises a body **1602** having a generally rounded-square or rounded-rectangular shape. An electronic display **1604** which is of a rectangular or rounded-rectangular shape is centrally positioned relative to the body **1602**. A belt-style rotatable ring **1606** is provided around a periphery of the body **1602**. As illustrated in FIGS. **16**A-**16**B, it is not required that the belt-style rotatable ring **1606** extend around the centrally located electronic display **1604** by a full 360 degrees of subtended arc, although it is preferable that it extend for at least 180 degrees therearound so that it can be conveniently contacted by the thumb on one side and one or more fingers on the other side and slidably rotated around the centrally located electronic display **1604**. The body **1602** can be mounted on a

backplate (not shown) and configured to provide an inward click capability when the user's hand presses inwardly on or near the belt-style rotatable ring **1606**. Illustrated on the electronic display **1604** is a population of background tick marks **1608** arcuately arranged within a range area on the electronic display **1604**. Although not circular in their distribution, the background tick marks **1608** are arcuately arranged in that they subtend an arc from one angular location to another angular location relative to a center of the electronic display **1604**. The particular arcuate arrangement of the background tick marks can be termed a rectangular arcuate arrangement, analogous to the way the minutewise tick marks of a rectangular or square clockface can be termed a rectangular arcuate arrangement. It is to be appreciated that the arcuate arrangement of tick marks can correspond to any of a variety of closed or semi-closed shapes without departing from the scope of the present teachings, including circular shapes, oval shapes, triangular shapes, rectangular shapes, pentagonal shapes, hexagonal shapes, and so forth. In alternative embodiments (not shown) the arrangement of background tick marks can be linear or quasi-linear, simply extending from left to right or bottom to top of the electronic display or in some other linear direction, wherein an arc is subtended between a first line extending from a reference point (such as the bottom center or center right side of the display) to the beginning of the range, and a second line extending from the reference point to the end of the tick mark range. A setpoint tick mark **1610** is displayed in a manner that is more visible to the user than the background tick marks **1608**, and a numerical setpoint representation **1612** is prominently displayed in the center of the electronic display **1604**.

As illustrated in FIGS. **16**A-**16**B, the user can perform a ring rotation to change the setpoint, with FIG. **16**B showing a new setpoint of 73 degrees along with a shift in the setpoint tick mark **1610** to a different arc location representative of the higher setpoint, and with a current temperature tick mark **1614** and current temperature numerical display **1616** appearing as shown. As with other embodiments, there is preferably a "sweeping" visual display of tick marks (not illustrated in FIGS. **16**A-**16**B) that sweeps from the current temperature tick mark **1614** to the setpoint temperature tick mark **1610**, analogous to the tick mark sweep shown in FIG. **14**, supra. With the exception of the differently implemented ring rotation facility and the changing of various display layouts to conform to the rectangular electronic display screen **1604**, operation of the thermostat **1600** is preferably similar to that of the circularly-shaped thermostat embodiments described supra. Thus, by way of non-limiting example, the thermostat **1600** is configured to provide a menu options screen (not shown) on electronic display **1604** that contains menu options such as Heat/Cool, Schedule, Energy, Settings, Away, and Done, and to function similarly to that shown in FIGS. **8**A-**8**C responsive to rotation of the belt-style rotatable ring **1606**, with the exception that instead of the electronically displayed words moving around in a circular trajectory, those words move around in a rectangular trajectory along the periphery of the electronic display **1604**.

FIGS. **17**A-**17**B illustrate a thermostat **1700** according to another alternative embodiment likewise having a different form factor that, while not believed to be quite as advantageous and/or elegant as the circular form factor, is nevertheless indeed within the scope of the present teachings. Thermostat **1700** comprises a body **1702** having a square or rectangular shape, and further comprises a rectangular electronic display **1704** that is centrally positioned relative to the body **1702**. The body **1702** and electronic display **1704** are configured, such as by virtue of appropriate mechanical couplings to a common underlying support structure **1702**, such that the body **1702** is manually rotatable by the user while the electronic display **1704** remains at a fixed horizontal angle, and further such that the body **1702** can be inwardly pressed by the user to achieve an inward click input, whereby the body **1702** itself forms and constitutes an inwardly pressable ring that is rotatable relative to an outwardly extending axis of rotation. With the exception of the different form factor assumed by the rotating ring/body **1702** and altered display layouts to conform to the rectangular electronic display screen **1704**, operation of the thermostat **1700** is preferably similar to that of the circularly-shaped thermostat embodiments described supra. Background tick marks **1708**, setpoint tick mark **1710**, current temperature tick mark **1714**, numerical current setpoint **1712**, and numerical current setpoint **1716** appear and function similarly to their counterpart numbered elements **1608**, **1610**, **1614**, **1612**, and **1616** of FIGS. **16**A-**16**B responsive to ring rotations and inward clicks. It is to be appreciated that the square or rectangular form factor of the body/rotatable ring **1702** and/or electronic display **1704** can be selected and/or and mixed-and-matched from among a variety of different shapes without departing from the scope of the present teachings, including circular shapes, oval shapes, triangular shapes, pentagonal shapes, hexagonal shapes, and so forth.

Although the foregoing has been described in some detail for purposes of clarity, it will be apparent that certain changes and modifications may be made without departing from the principles thereof. By way of example, it is within the scope of the present teachings for the rotatable ring of the above-described thermostat to be provided in a "virtual," "static," or "solid state" form instead of a mechanical form, whereby the outer periphery of the thermostat body contains a touch-sensitive material similar to that used on touchpad computing displays and smartphone displays. For such embodiments, the manipulation by the user's hand would be a "swipe" across the touch-sensitive material, rather than a literal rotation of a mechanical ring, the user's fingers sliding around the periphery but not actually causing mechanical movement. This form of user input, which could be termed a "virtual ring rotation," "static ring rotation", "solid state ring rotation", or a "rotational swipe", would otherwise have the same purpose and effect of the above-described mechanical rotations, but would obviate the need for a mechanical ring on the device. Although not believed to be as desirable as a mechanically rotatable ring insofar as there may be a lesser amount of tactile satisfaction on the part of the user, such embodiments may be advantageous for reasons such as reduced fabrication cost. By way of further example, it is within the scope of the present teachings for the inward mechanical pressability or "inward click" functionality of the rotatable ring to be provided in a "virtual" or "solid state" form instead of a mechanical form, whereby an inward pressing effort by the user's hand or fingers is detected using internal solid state sensors (for example, solid state piezoelectric transducers) coupled to the outer body of the thermostat. For such embodiments, the inward pressing by the user's hand or fingers would not cause actual inward movement of the front face of the thermostat as with the above-described embodiments, but would otherwise have the same purpose and effect as the above-described "inward clicks" of the rotatable ring. Optionally, an audible beep or clicking sound can be provided from an internal speaker or other sound transducer, to provide feedback that the user has sufficiently pressed inward on the rotatable ring or virtual/solid state rotatable ring. Although not believed to be as desirable as the previously described embodiments, whose inwardly moving rotatable ring and sheet-metal style

rebounding mechanical "click" has been found to be particularly satisfying to users, such embodiments may be advantageous for reasons including reduced fabrication cost. It is likewise within the scope of the present teachings for the described thermostat to provide both the ring rotations and inward clicks in "virtual" or "solid state" form, whereby the overall device could be provided in fully solid state form with no moving parts at all.

By way of further example, although described above as having ring rotations and inward clicks as the exclusive user input modalities, which has been found particularly advantageous in terms of device elegance and simplicity, it is nevertheless within the scope of the present teachings to alternatively provide the described thermostat with an additional button, such as a "back" button. In one option, the "back" button could be provided on the side of the device, such as described in the commonly assigned U.S. Ser. No. 13/033,573, supra. In other embodiments, plural additional buttons, such as a "menu" button and so forth, could be provided on the side of the device. For one embodiment, the actuation of the additional buttons would be fully optional on the part of the user, that is, the device could still be fully controlled using only the ring rotations and inward clicks. However, for users that really want to use the "menu" and "back" buttons because of the habits they may have formed with other computing devices such as smartphones and the like, the device would accommodate and respond accordingly to such "menu" and "back" button inputs.

By way of even further example, other forms of user input modalities could be provided by the above-described thermostat as additions and/or alternative to the above-described ring rotations and inward clicks without necessarily departing from the scope of the present teachings. Examples include optically sensed gesture-based user inputs similar to those provided with modern video game consoles, and voice inputs implemented using known speech recognition algorithms. It is to be appreciated that there are many alternative ways of implementing both the processes and apparatuses described herein. Accordingly, the present embodiments are to be considered as illustrative and not restrictive, and the inventive body of work is not to be limited to the details given herein, which may be modified within the scope and equivalents of the appended claims.

What is claimed is:

1. In a programmable device for controlling an HVAC system, a method for interacting with a user of the programmable device, comprising:

displaying a plurality of background tick marks arcuately arranged within a range area on an electronic display that is centrally mounted on a body of the programmable device, said electronic display and said body each being rounded in shape;

displaying a setpoint tick mark on the electronic display within the range area such that the setpoint tick mark is more prominently visible to the user than the background tick marks, the setpoint tick mark representing a setpoint temperature;

displaying a numerical representation of the setpoint temperature in a central location on the rounded electronic display; and

displaying on the rounded electronic display a background color having a red and/or orange shade when the programmable device is calling for heating from the HVAC system.

2. A method according to claim **1** wherein the background color is displayed with an intensity that varies according to an amount of heating to be used to reach the setpoint temperature.

3. A method according to claim **1** further comprising displaying a current temperature tick mark on the rounded electronic display within the range area such that the current temperature tick mark is more prominent than the background tick marks, the current temperature tick mark representing a current temperature.

4. A method according to claim **3** further comprising displaying a numerical representation of the current temperature on the rounded electronic display in close proximity to said current temperature tick mark.

5. A method according to claim **1** further comprising receiving input from a user at least in part using a rotatable ring surrounding the rounded electronic display, the input representing a change in the setpoint temperature.

6. A method according to claim **5** further comprising moving the setpoint tick mark in response to and in accordance with the received input such that the change in setpoint is visible to the user.

7. A programmable device for controlling an HVAC system adapted and configured to interface with a user according to the method of claim **1**.

8. A non-transitory computer-readable medium having executable instructions that, when executed by a processor of a programmable device for controlling an HVAC system, cause the programmable device to interface with a user thereof according to the method of claim **1**.

9. A method of claim **1** further comprising:

displaying a menu including a plurality of user selectable options in an arcuate area on the electronic display that is centrally mounted on the body of the programmable device;

receiving input from a user at least in part using a rotatable ring surrounding the rounded electronic display; and

highlighting different user selectable options in response to and in accordance with the received input.

10. A method according to claim **9**, said electronic display and said body each being rounded in shape, wherein the arcuate area is a circular outer area of the rounded electronic display, and wherein the plurality of user selectable options are distributed about the circular area and are rotated about the rounded electronic display in response to the received input.

11. A method according to claim **10** wherein the highlighting includes a highlighting window that remains in a fixed position relative to the device while the plurality of user selectable options are progressively rotated through the window such that only one of the user selectable options appears within the window.

12. A method according to claim **11** wherein said receiving input from the user includes:

detecting an inward pressure from the user placed on the device; and

regarding as the user's selected option the user selectable option that appears within the highlighting window at a time of the detected inward pressure.

13. In a programmable device for controlling an HVAC system, a method for interacting with a user of the programmable device, comprising:

displaying a plurality of background tick marks arcuately arranged within a range area on an electronic display that is centrally mounted on a body of the programmable device, said electronic display and said body each being rounded in shape;

displaying a setpoint tick mark on the electronic display within the range area such that the setpoint tick mark is more prominently visible to the user than the background tick marks, the setpoint tick mark representing a setpoint temperature;

displaying a numerical representation of the setpoint temperature in a central location on the rounded electronic display; and

displaying on the rounded electronic display a background color having a bluish shade when the device is calling for cooling from the HVAC system.

14. A method according to claim **13** wherein the background color is displayed with an intensity that varies according to an amount of cooling to be used to reach the setpoint temperature.

15. A programmable device for controlling an HVAC system adapted and configured to interface with a user according to the method of claim **13**.

16. A non-transitory computer-readable medium having executable instructions that, when executed by a processor of a programmable device for controlling an HVAC system, cause the programmable device to interface with a user thereof according to the method of claim **13**.

17. A method according to claim **13** further comprising displaying a current temperature tick mark on the rounded electronic display within the range area such that the current temperature tick mark is more prominent than the background tick marks, the current temperature tick mark representing a current temperature.

18. A method according to claim **17** further comprising displaying a numerical representation of the current temperature on the rounded electronic display in close proximity to said current temperature tick mark.

19. A method according to claim **13** further comprising receiving input from a user at least in part using a rotatable ring surrounding the rounded electronic display, the input representing a change in the setpoint temperature.

20. A method according to claim **19** further comprising moving the setpoint tick mark in response to and in accordance with the received input such that the change in setpoint is visible to the user.

21. In a programmable device for controlling an HVAC system, a method for interacting with a user of the programmable device, comprising:

displaying a visible portion of a schedule plot on an electronic display that is centrally mounted on a body of the programmable device, the schedule plot having a time axis and including a plurality of programmed setpoints disposed at respective locations along the time axis;

receiving input from the user by user rotation of a rotatable ring surrounding the electronic display;

progressively changing the visible portion of the schedule plot in response to the received input; and

displaying a stationary cursor overlaid on the displayed visible portion of the schedule plot, the cursor being representative of a time value by virtue of its location along the time axis of the schedule plot;

wherein the changing the visible portion includes moving the schedule plot in a direction of the time axis relative to the stationary cursor such that a progression of time intervals is represented on the electronic display as a function of the received user input;

wherein each said programmed setpoint has an effective time that is characterized by the location of the programmed setpoint along said time axis, and wherein each said programmed setpoint further has a temperature value that is characterized by the location of the programmed setpoint along a temperature axis of the schedule plot.

22. A method according to claim **21**, wherein said time axis is oriented along a horizontal direction of the rounded electronic display, and wherein said temperature axis is disposed along a vertical direction of the rounded electronic display.

23. A method according to claim **22** wherein the setpoint effective time and setpoint temperature value of each setpoint can be adjusted by the user using the rotatable ring.

24. A programmable device for controlling an HVAC system adapted and configured to interface with a user according to the method of claim **21**.

25. A non-transitory computer-readable medium having executable instructions that, when executed by a processor of a programmable device for controlling an HVAC system, cause the programmable device to interface with a user thereof according to the method of claim **21**.

26. A programmable device for controlling an HVAC system comprising:

an electronic display positioned inside an outer ring that is user rotatable to generate rotation input and user pressable along a direction of an axis of rotation of the outer ring to generate press input; and

a processor adapted and configured to drive the electronic display responsive to rotation input generated by user rotation of the outer ring and press input generated by user pressing of the outer ring,

wherein the processor is programmed to cause the electronic display to show recent energy usage performance information for a succession of recent historical time intervals that appear on the electronic display according to rotation input generated by user rotation of the outer ring.

27. A device according to claim **26**, wherein each of the outer ring and the electronic display is circular in shape, and wherein the energy performance information for each time interval is displayed in a separate window, the electronic display showing transitions between adjacent historical intervals using animated lateral movement transitions between windows that are responsive to rotation input generated by user rotation of the outer ring.

28. A device according to claim **27**, wherein the device is a programmable thermostat.

29. A device according to claim **28**, the device being further programmed according to a method comprising:

displaying a menu including a plurality of user selectable options in an arcuate area on the electronic display, said user selectable options including an energy information display option;

highlighting different ones of said user selectable options in response to and in accordance with rotation input generated by user rotation of the outer ring;

detecting press input generated by user pressing of the outer ring; and

regarding as a selected option from said menu the user selectable option that is highlighted at a time of said detecting press input generated by user pressing;

wherein said recent energy usage performance information is shown responsive to selection of the energy information display option from said menu.

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